Yellowstone River Reach Narratives

Reach PC1

County	Park	**Upstream River Mile**	564.8
Classification	CS: Confined straight	**Downstream River Mile**	560.2
General Location	Gardiner to Little Trail Cr.	**Length**	4.60 mi (7.40 km)

General Comments

Narrative Summary

Reach PC1 is the upstream-most reach of the project area, beginning at Gardiner Montana, and extending northward almost five miles to the Trail Creek confluence. Reach PC1 is confined/straight reach type and shows minimal impact in terms of flow alterations, bank armoring, and side channel loss. The bankfull area has remained essentially unchanged since 1950. Land use is dominated by non-irrigated agriculture, with some conversion of flood irrigation to sprinkler from 1950 to 2011. There are over 300 acres of urban/exurban development in the reach, dominated by the town of Gardiner. Although the development in Gardiner is very close to the river, it is located high on bluffs that are outside of the Channel Migration Zone (CMZ) and floodplain. The bluffs are composed of glacial outwash deposits that are very coarse and erosion resistant. The total CMZ area in Reach PC1 is only 115 acres, and there is essentially no riparian zone in this reach. This section of river is relatively steep, with steep boulder runs and associated wave trains that make it a popular stretch of river for recreational white water rafting. There is one boat ramp in the reach at RM 561.5, and the Queen of the Waters Fishing Access Site is located at RM 563.

This area of the upper Yellowstone River basin experienced three severe floods in the last 20 years. The largest floods were in 1996 and 1997, when the 32,200 cfs peak flow measured at the Corwin Springs gage exceeded a 100-year flood for those two years in a row. The 1974 and 2011 floods were major as well, with both events exceeding 30,000 cfs. The Corwin Springs gage is located downstream of Reach PC1 at the Corwin Springs Bridge.

CEA-Related observations in Reach PC1 include:
•Urban/Exurban development at Gardiner

No reach-specific Practices have been identified for this reach.

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Corwin Springs

Flood History

Year	Date	Flow on Date	Return Interval
1927	Jun 27	25,000	10-25 yr
1971	Jun 23	25,200	10-25 yr
1928	May 26	25,300	10-25 yr
1911	Jun 13	25,800	10-25 yr
2010	Jun 5	26,000	10-25 yr
2011	Jun 30	30,300	50-100 yr
1974	Jun 17	30,900	50-100 yr
1918	Jun 14	32,000	50-100 yr
1997	Jun 6	32,200	>100-yr
1996	Jun 10	32,200	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6191500	6186500
Location	Corwin Springs	Ystone Lake
Period of Record	1890-2012	1923-2012
Distance To (miles)	3.0	

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	8,370	16,800	21,300	24,100	29,800	32,100	37,500	NA	1,760
Regulated	8,370	16,800	21,300	24,100	29,800	32,100	37,500	NA	1,680
% Change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	NA	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/28/2005	color	1-meter pixels	6192500	2210
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/22/2009	Color	1-meter pixels	6192500	6990
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	08/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

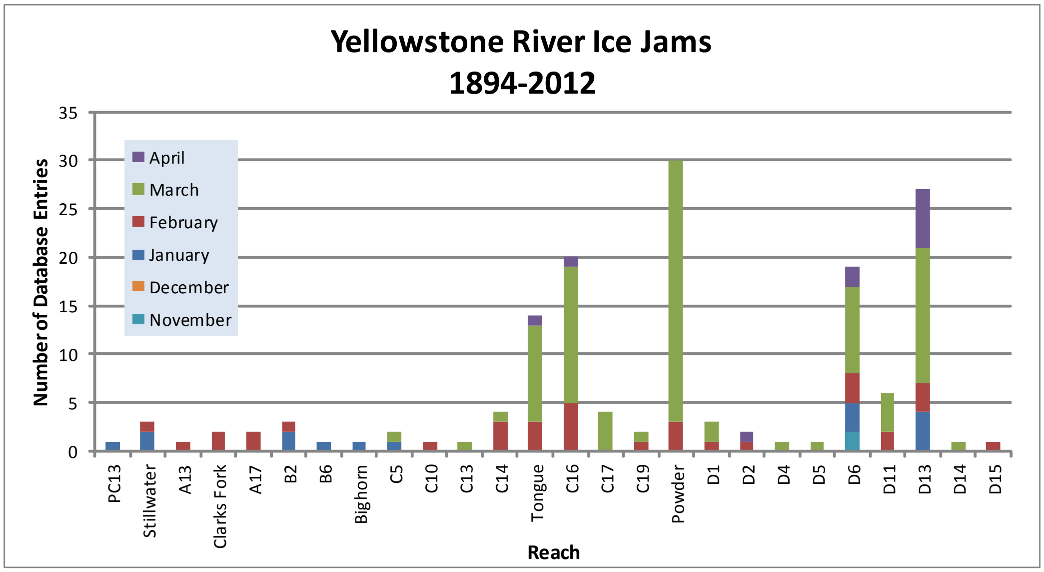
Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	23,391		1.00	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	2,345,264		1.00	1950 to 2001:	0.00%
Change 1950 - 2001	**2,321,873**		**0.00**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
0	0	115	0	0%	0	0	0%

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
0.0	0.0	0.0	1.4	0.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	2	2	2	0	0.1%	0.1%	0.1%	0.0%
	Totals	**2**	**2**	**2**	**0**	**0.1%**	**0.1%**	**0.1%**	**0.0%**
Agricultural Land									
	Non-Irrigated	1,605	1,433	1,362	1,364	84.5%	75.4%	71.7%	71.8%
	Irrigated	42	35	36	36	2.2%	1.8%	1.9%	1.9%
	Totals	**1,648**	**1,468**	**1,398**	**1,399**	**86.7%**	**77.3%**	**73.6%**	**73.7%**
Channel									
	Channel	107	110	110	110	5.6%	5.8%	5.8%	5.8%
	Totals	**107**	**110**	**110**	**110**	**5.6%**	**5.8%**	**5.8%**	**5.8%**
ExUrban									
	ExUrban Other	0	6	6	6	0.0%	0.3%	0.3%	0.3%
	ExUrban Undeveloped	0	0	19	19	0.0%	0.0%	1.0%	1.0%
	ExUrban Industrial	31	107	107	107	1.7%	5.6%	5.6%	5.6%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	25	27	27	0.0%	1.3%	1.4%	1.4%
	Totals	**31**	**138**	**158**	**158**	**1.7%**	**7.2%**	**8.3%**	**8.3%**
Transportation									
	Public Road	60	58	58	58	3.2%	3.1%	3.1%	3.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**60**	**58**	**58**	**58**	**3.2%**	**3.1%**	**3.1%**	**3.1%**
Urban									
	Urban Other	1	27	27	27	0.1%	1.4%	1.4%	1.4%
	Urban Residential	16	30	77	77	0.9%	1.6%	4.0%	4.0%
	Urban Commercial	30	57	71	71	1.6%	3.0%	3.7%	3.7%
	Urban Undeveloped	4	10	0	0	0.2%	0.5%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**52**	**125**	**175**	**175**	**2.7%**	**6.6%**	**9.2%**	**9.2%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	36	36	0.0%	0.0%	2.6%	2.6%	0.0%	2.6%	0.0%	2.6%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	42	35	0	0	2.6%	2.4%	0.0%	0.0%	-0.2%	-2.4%	0.0%	-2.6%
	Totals	**42**	**35**	**36**	**36**	**2.6%**	**2.4%**	**2.6%**	**2.6%**	**-0.2%**	**0.2%**	**0.0%**	**0.0%**

Non-Irrigated												
Multi-Use	1,605	1,433	1,362	1,364	97.4%	97.6%	97.4%	97.4%	0.2%	-0.2%	0.0%	0.0%
Hay/Pasture	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	**1,605**	**1,433**	**1,362**	**1,364**	**97.4%**	**97.6%**	**97.4%**	**97.4%**	**0.2%**	**-0.2%**	**0.0%**	**0.0%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950’s, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The “Riparian Turnover” values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	0.0	0.0	0.0	0.0	**0.0**
Acres/Valley Mile	0.0	0.0	0.0	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.05	0.28%	0.42	0.00	0.00	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County	Park	**Upstream River Mile**	560.2
Classification	CM: Confined meandering	**Downstream River Mile**	557.2
General Location	Devil's Slide area	**Length**	3.00 mi (4.83 km)

General Comments

Narrative Summary

Reach PC2 is located north of Gardiner near Devil's Slide. The reach is three miles long, and is confined by glacial terraces that taper in the northward direction as the river approaches Yankee Jim Canyon. This reach a contains over 3,000 feet of rock riprap, all of which is against the toe of the terrace where the river flows adjacent to Highway 89 on the east side of the river. About one third or 1,200 feet of that riprap was built since 2001, where older riprap was extended against the highway. The riprap covers 9.3 percent of the total bankline. Migration rates are very low, and the total CMZ acreage is 111 acres. Land use is dominated by non-irrigated agriculture, and irrigated agriculture has seen some conversion from flood to sprinkler and pivot. In 1950, there were 152 acres of land in PC2 under flood irrigation, and in 2011 there were none. Whereas there was no sprinkler or pivot irrigation in 1950, now there are 133 acres of sprinkler and 62 acres under flood irrigation. The Brogans Landing Fishing Access Site is located in the lower end of the reach.

This area of the upper Yellowstone River basin experienced three severe floods in the last 20 years. The largest floods were in 1996 and 1997, when the 32,200 cfs peak flow measured at the Corwin Springs gage exceeded a 100-year flood for those two years in a row. The 1974 and 2011 floods were major as well, with both events exceeding 30,000 cfs. The Corwin Springs gage is located downstream of Reach PC2 at the Corwin Springs Bridge.

CEA-Related observations in Reach PC2 include:
•Urban/Exurban development at Gardiner

No reach-specific Practices have been identified for this reach.

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Corwin Springs

Flood History

Year	Date	Flow on Date	Return Interval
1927	Jun 27	25,000	10-25 yr
1971	Jun 23	25,200	10-25 yr
1928	May 26	25,300	10-25 yr
1911	Jun 13	25,800	10-25 yr
2010	Jun 5	26,000	10-25 yr
2011	Jun 30	30,300	50-100 yr
1974	Jun 17	30,900	50-100 yr
1918	Jun 14	32,000	50-100 yr
1997	Jun 6	32,200	>100-yr
1996	Jun 10	32,200	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6191500	6186500
Location	Corwin Springs	Ystone Lake
Period of Record	1890-2012	1923-2012
Distance To (miles)	0.0	

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	8,800	17,600	22,300	25,200	31,100	33,500	39,100	NA	1,760
Regulated	8,800	17,600	22,300	25,200	31,100	33,500	39,100	NA	1,680
% Change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	NA	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/22/2009	Color	1-meter pixels	6192500	6990
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	08/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

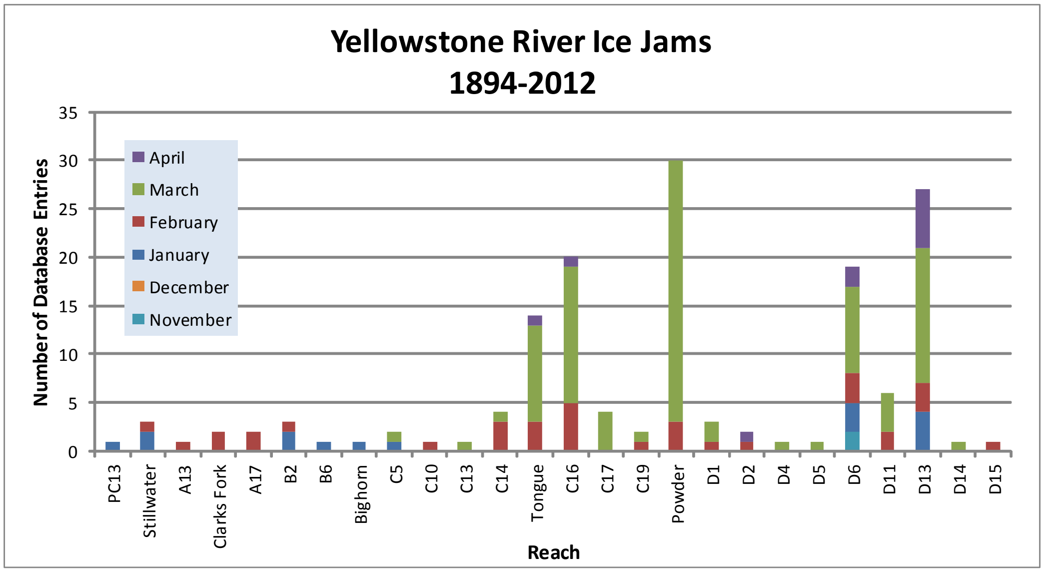
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	1,788	5.5%	3,043	9.3%	1,255
	Feature Type Totals	**1,788**	**5.5%**	**3,043**	**9.3%**	**1,255**
	Reach Totals	**1,788**	**5.5%**	**3,043**	**9.3%**	**1,255**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	16,400		1.00	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	16,392		1.00	1950 to 2001:	0.00%
Change 1950 - 2001	**-9**		**0.00**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as “Restricted Migration Areas” (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as “Avulsion Potential Zones”.

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
0	0	111	0	0%	0	0	0%

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
0.0	0.0	0.0	1.5	0.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	21	32	36	24	1.6%	2.4%	2.7%	1.8%
	Totals	**21**	**32**	**36**	**24**	**1.6%**	**2.4%**	**2.7%**	**1.8%**
Agricultural Land									
	Non-Irrigated	908	882	859	833	68.2%	66.2%	64.5%	62.5%
	Irrigated	251	223	156	194	18.8%	16.7%	11.7%	14.6%
	Totals	**1,159**	**1,105**	**1,015**	**1,027**	**87.0%**	**83.0%**	**76.2%**	**77.1%**
Channel									
	Channel	107	100	100	100	8.1%	7.5%	7.5%	7.5%
	Totals	**107**	**100**	**100**	**100**	**8.1%**	**7.5%**	**7.5%**	**7.5%**
ExUrban									
	ExUrban Other	0	16	16	16	0.0%	1.2%	1.2%	1.2%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	9	0	0	0.0%	0.7%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	9	34	129	129	0.7%	2.6%	9.7%	9.7%
	Totals	**9**	**59**	**145**	**145**	**0.7%**	**4.5%**	**10.9%**	**10.9%**
Transportation									
	Public Road	36	36	36	36	2.7%	2.7%	2.7%	2.7%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**36**	**36**	**36**	**36**	**2.7%**	**2.7%**	**2.7%**	**2.7%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	125	133	0.0%	0.0%	12.3%	12.9%	0.0%	12.3%	0.6%	12.9%
	Pivot	0	0	0	62	0.0%	0.0%	0.0%	6.0%	0.0%	0.0%	6.0%	6.0%
	Flood	251	223	31	0	21.6%	20.2%	3.1%	0.0%	-1.5%	-17.1%	-3.1%	-21.6%
	Totals	**251**	**223**	**156**	**194**	**21.6%**	**20.2%**	**15.4%**	**18.9%**	**-1.5%**	**-4.8%**	**3.5%**	**-2.7%**

Non-Irrigated												
Multi-Use	867	793	813	810	74.8%	71.8%	80.1%	78.8%	-3.0%	8.3%	-1.2%	4.0%
Hay/Pasture	41	89	46	23	3.5%	8.0%	4.5%	2.2%	4.5%	-3.5%	-2.3%	-1.3%
Totals	**908**	**882**	**859**	**833**	**78.4%**	**79.8%**	**84.6%**	**81.1%**	**1.5%**	**4.8%**	**-3.5%**	**2.7%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	0.0	2.5	2.4	0.0	**4.9**
Acres/Valley Mile	0.0	0.9	0.9	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.01	0.20%	0.25	0.00	0.01	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County	Park	**Upstream River Mile**	557.2
Classification	CS: Confined straight	**Downstream River Mile**	546.8
General Location	Corwin Springs to Carbella; Yankee Jim Canyon	**Length**	10.40 mi (16.74 km)

General Comments

Narrative Summary

Reach PC3 is located north of Gardiner, extending from Corwin Springs to Carbella. This reach is highly confined and by glacial terraces on its upper end, and Archean-age gneiss on its lower end. As an Archean-age rock unit, the gneiss is over 2.5 billion years old. This bedrock confined section of river is known as Yankee Jim Canyon, which hosts a steep series of drops that create the most challenging whitewater section of the Yellowstone River outside of Yellowstone National Park. “Yankee Jim” George was a well-known character of the area; he came from the east in the late 1800s to settle on a newly built wagon road that extended from Bozeman to Mammoth Hot Springs in Yellowstone National Park. For 20 years Yankee Jim ran the National Park Toll Road. One hundred years later, Yankee Jim Canyon is highly popular as a recreational resource for both rafting and fishing. There are two boat ramps in the reach, located above and below the canyon. The Slip & Slide (RM 552) and Crystal Cross (RM 548) Fishing Access Sites provide river access but have no boat ramps.

Reach PC3 contains over three miles of bank armor, most of which is rock riprap that protects the highway at the entrance to Yankee Jim Canyon. Of those three miles, 700 feet was constructed since 2001. Channel migration is extremely localized in the reach, and is concentrated at the toe of an alluvial fan at the mouth of Cedar Creek that impinges on the river from the east.

Similar to other reaches in Park County, the extent of flood irrigation has dropped in the reach since 1950, and the amount of sprinkler irrigation has increased. Even so, there has been a net loss of irrigated land of over 200 acres in the reach as exurban land uses have expanded.

This area of the upper Yellowstone River basin experienced three severe floods in the last 20 years. The largest floods were in 1996 and 1997, when the 32,200 cfs peak flow measured at the Corwin Springs gage exceeded a 100-year flood for those two years in a row. The 1974 and 2011 floods were major as well, with both events exceeding 30,000 cfs.

CEA-Related observations in Reach PC3 include:
•Conversion of flood irrigation to sprinkler
•Net loss of irrigated land

No reach-specific Practices have been identified for this reach.

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Corwin Springs

Flood History

Year	Date	Flow on Date	Return Interval
1927	Jun 27	25,000	10-25 yr
1971	Jun 23	25,200	10-25 yr
1928	May 26	25,300	10-25 yr
1911	Jun 13	25,800	10-25 yr
2010	Jun 5	26,000	10-25 yr
2011	Jun 30	30,300	50-100 yr
1974	Jun 17	30,900	50-100 yr
1918	Jun 14	32,000	50-100 yr
1997	Jun 6	32,200	>100-yr
1996	Jun 10	32,200	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6192500	6191500
Location	Livingston	Corwin Springs
Period of Record	1929-2015	1890-2012
Distance To (miles)	40.2	0.0

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	8,800	17,600	22,300	25,200	31,100	33,500	39,100	1,230	1,760
Regulated	8,800	17,600	22,300	25,200	31,100	33,500	39,100	1,220	1,680
% Change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.81%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/27/2005	color	1-meter pixels	6192500	2250
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/22/2009	Color	1-meter pixels	6192500	6990
2009	NAIP	6/27/2009	Color	1-meter pixels	6192500	15200
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

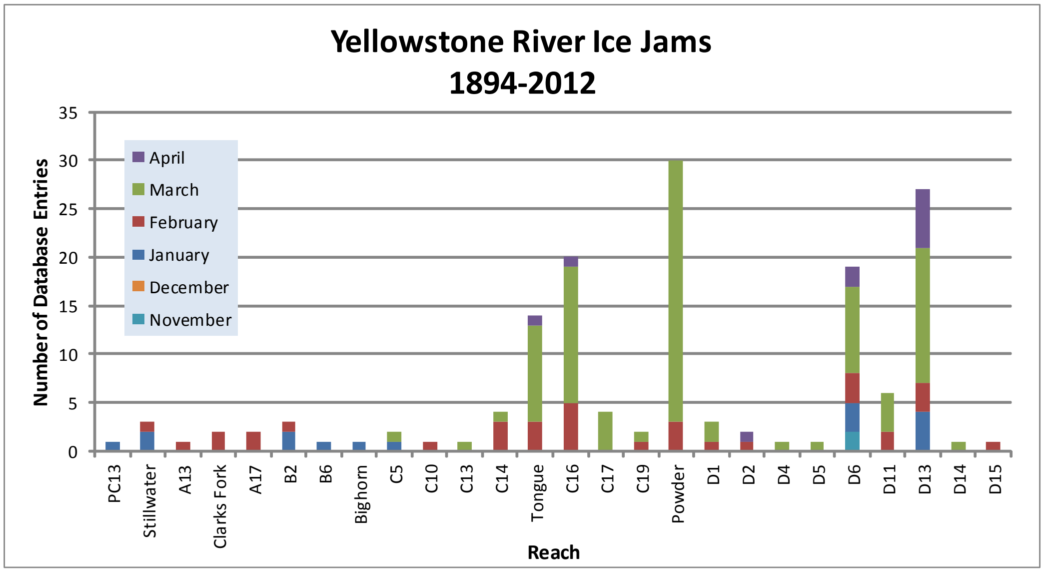
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	15,624	14.3%	16,335	15.0%	711
	Flow Deflectors	227	0.2%	227	0.2%	0
	Between Flow Deflectors	67	0.1%	67	0.1%	0
	Feature Type Totals	**15,917**	**14.6%**	**16,628**	**15.2%**	**711**
	Reach Totals	**15,917**	**14.6%**	**16,628**	**15.2%**	**711**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	54,600		1.00	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	54,596	1,677	1.03	1950 to 2001:	3.07%
Change 1950 - 2001	**-4**		**0.03**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
74	148	335	0	0%	0	0	0%

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
0.0	0.0	0.0	4.2	1.3

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	21	32	36	24	0.5%	0.7%	0.8%	0.5%
	Totals	**21**	**32**	**36**	**24**	**0.5%**	**0.7%**	**0.8%**	**0.5%**
Agricultural Land									
	Non-Irrigated	908	882	859	833	20.1%	19.5%	19.0%	18.4%
	Irrigated	251	223	156	194	5.5%	4.9%	3.5%	4.3%
	Totals	**1,159**	**1,105**	**1,015**	**1,027**	**25.6%**	**24.4%**	**22.4%**	**22.7%**
Channel									
	Channel	107	100	100	100	2.4%	2.2%	2.2%	2.2%
	Totals	**107**	**100**	**100**	**100**	**2.4%**	**2.2%**	**2.2%**	**2.2%**
ExUrban									
	ExUrban Other	0	16	16	16	0.0%	0.4%	0.4%	0.4%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	9	0	0	0.0%	0.2%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	9	34	129	129	0.2%	0.8%	2.9%	2.9%
	Totals	**9**	**59**	**145**	**145**	**0.2%**	**1.3%**	**3.2%**	**3.2%**
Transportation									
	Public Road	36	36	36	36	0.8%	0.8%	0.8%	0.8%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**36**	**36**	**36**	**36**	**0.8%**	**0.8%**	**0.8%**	**0.8%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	92	188	0.0%	0.0%	2.5%	5.1%	0.0%	2.5%	2.6%	5.1%
	Pivot	0	0	0	32	0.0%	0.0%	0.0%	0.9%	0.0%	0.0%	0.9%	0.9%
	Flood	635	535	272	184	15.6%	13.7%	7.4%	5.0%	-2.0%	-6.3%	-2.4%	-10.6%
	Totals	**635**	**535**	**364**	**404**	**15.6%**	**13.7%**	**9.9%**	**11.0%**	**-2.0%**	**-3.7%**	**1.1%**	**-4.6%**

Non-Irrigated											
Multi-Use	3,400	3,299	3,113	3,116	83.6%	84.3%	84.7%	84.6%	0.7%	0.4%	-0.1%	1.0%
Hay/Pasture	33	81	200	164	0.8%	2.1%	5.4%	4.4%	1.2%	3.4%	-1.0%	3.6%
Totals	**3,433**	**3,380**	**3,313**	**3,280**	**84.4%**	**86.3%**	**90.1%**	**89.0%**	**2.0%**	**3.7%**	**-1.1%**	**4.6%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	0.3	7.3	6.4	0.0	**14.0**
Acres/Valley Mile	0.0	0.7	0.6	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.02	0.15%	0.72	0.00	0.01	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Yellowstone River Reach Narratives — Reach PC4

County	Park	**Upstream River Mile**	546.8
Classification	CM: Confined meandering	**Downstream River Mile**	543.2
General Location	Carbella to Hwy 89 Br.	**Length**	3.60 mi (5.79 km)

General Comments

Narrative Summary

Reach PC4 extends from Carbella to the Highway 89 Bridge at Point of Rocks in the upper Paradise Valley. The reach is classified as confined meandering, indicating that it has some sinuosity, yet migration rates are low due to lateral confinement.

Flow deflectors and rock riprap cover about 800 feet of bankline in Reach PC4, which is about 2 percent of the total streambank length. All of this armor was in place prior to 2001.

Similar to other reaches in Park County, the extent of flood irrigation has dropped in the reach since 1950, and the amount of sprinkler and pivot irrigation has increased. Reach PC4 has seen a net expansion of about 150 acres of irrigated lands since 1950, with about half of the expansion into sprinkler irrigation and the other half into pivot.

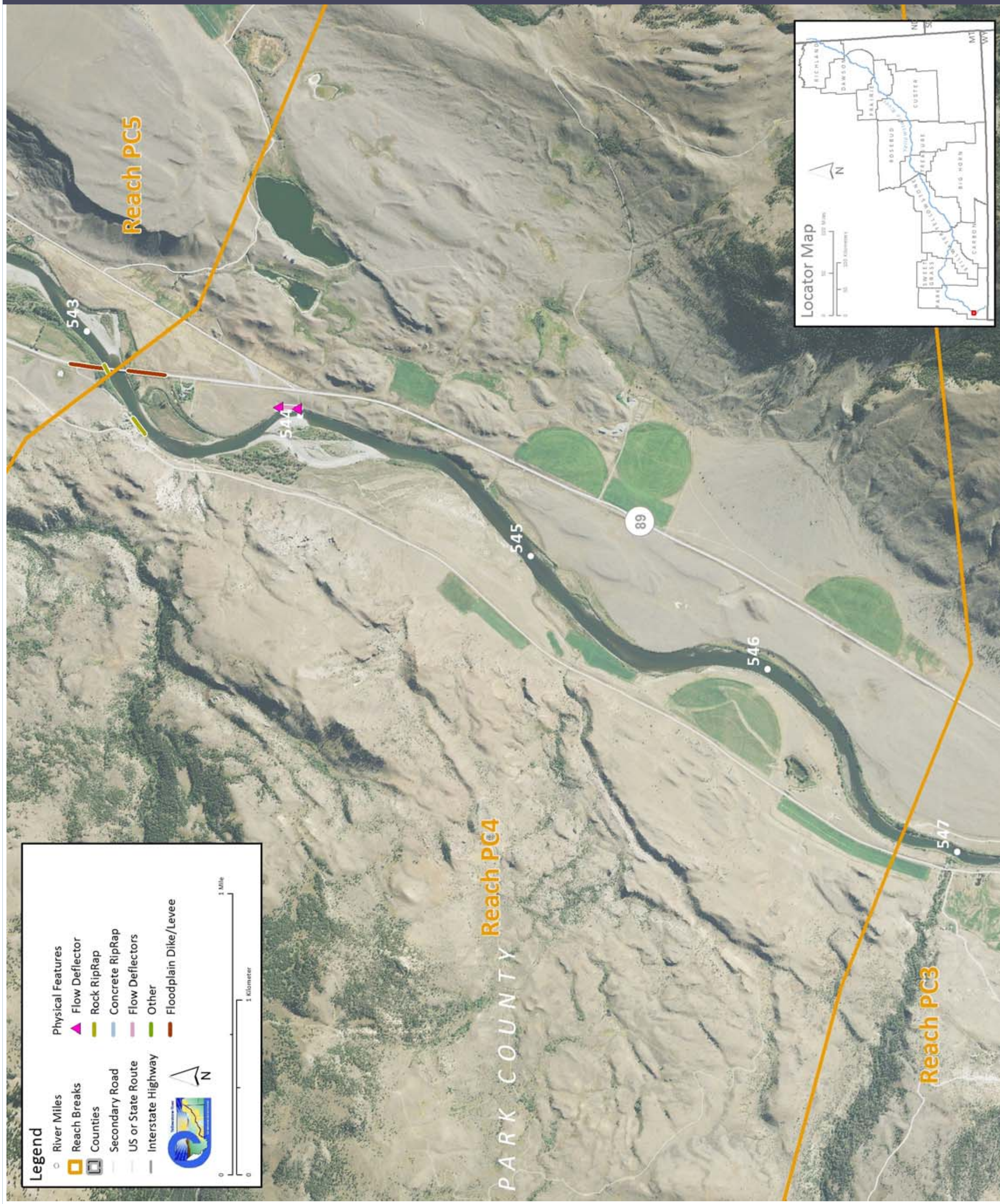
Reach PC4 marks the entrance of the Yellowstone River into the Paradise Valley. This is geomorphically indicated by the onset of point bar formation and sediment storage in the channel. One large bar deposit located about ¾ mile of the Highway 89 bridge has driven almost 300 feet of bank movement since 1950. As result, the Channel Migration Zone area in this reach has expanded relative to upstream, with an erosion buffer of 258 feet assigned to the alluvial edge of the river. Reach PC4 also has over 2,000 feet of active side channels.

This area of the upper Yellowstone River basin experienced three severe floods in the last 20 years. The largest floods were in 1996 and 1997, when the 32,200 cfs peak flow measured at the Corwin Springs gage exceeded a 100-year flood for those two years in a row. The 1974 and 2011 floods were major as well, with both events exceeding 30,000 cfs. The Corwin Springs gage is located upstream of Reach PC4 at the Corwin Springs Bridge.

CEA-Related observations in Reach PC4 include:
- Increased bank migration and Channel Migration Zone area entering Paradise Valley
- Net expansion of irrigated lands

No reach-specific Practices have been identified for this reach.

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Corwin Springs

Flood History

Year	Date	Flow on Date	Return Interval
1927	Jun 27	25,000	10-25 yr
1971	Jun 23	25,200	10-25 yr
1928	May 26	25,300	10-25 yr
1911	Jun 13	25,800	10-25 yr
2010	Jun 5	26,000	10-25 yr
2011	Jun 30	30,300	50-100 yr
1974	Jun 17	30,900	50-100 yr
1918	Jun 14	32,000	50-100 yr
1997	Jun 6	32,200	>100-yr
1996	Jun 10	32,200	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6192500	6191500
Location	Livingston	Corwin Springs
Period of Record	1929-2015	1890-2012
Distance To (miles)	36.6	10.4

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,560	19,100	24,000	27,100	33,400	36,000	41,900	1,240	1,760
Regulated	9,500	19,000	23,900	27,000	33,400	36,000	41,900	1,230	1,680
% Change	-0.63%	-0.52%	-0.42%	-0.37%	0.00%	0.00%	0.00%	-0.81%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/27/2005	color	1-meter pixels	6192500	2250
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	6/27/2009	Color	1-meter pixels	6192500	15200
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

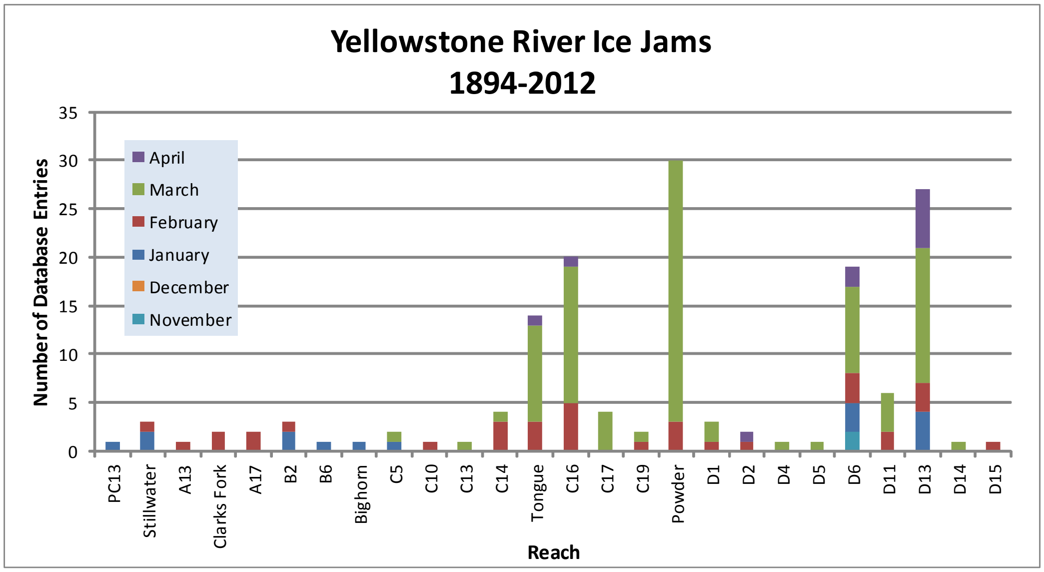
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	367	1.0%	367	1.0%	0
	Flow Deflectors	150	0.4%	147	0.4%	-3
	Between Flow Deflectors	283	0.7%	287	0.8%	4
	Feature Type Totals	**801**	**2.1%**	**801**	**2.1%**	**0**
Floodplain Control						
	Floodplain Dike/Levee	918	2.4%	918	2.4%	0
	Feature Type Totals	**918**	**2.4%**	**918**	**2.4%**	**0**
	Reach Totals	**1,718**	**4.5%**	**1,718**	**4.5%**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	19,086	2,189	1.11	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	19,119	2,837	1.15	1950 to 2001:	3.02%
Change 1950 - 2001	**34**	**648**	**0.03**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
129	258	308	3	1%	0	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	3	0.9%
	Totals	**3**	**0.9%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
5.5	0.8	0.9	3.4	0.8

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	8	2	4	4	0.5%	0.1%	0.2%	0.2%
	Totals	**8**	**2**	**4**	**4**	**0.5%**	**0.1%**	**0.2%**	**0.2%**
Agricultural Land									
	Non-Irrigated	1,408	1,294	1,392	1,253	83.1%	76.3%	82.1%	73.9%
	Irrigated	63	167	63	190	3.7%	9.8%	3.7%	11.2%
	Totals	**1,471**	**1,460**	**1,455**	**1,443**	**86.8%**	**86.2%**	**85.9%**	**85.1%**
Channel									
	Channel	186	179	180	181	11.0%	10.6%	10.6%	10.7%
	Totals	**186**	**179**	**180**	**181**	**11.0%**	**10.6%**	**10.6%**	**10.7%**
ExUrban									
	ExUrban Other	0	0	0	2	0.0%	0.0%	0.0%	0.1%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	9	13	22	0.0%	0.5%	0.7%	1.3%
	Totals	**0**	**9**	**13**	**23**	**0.0%**	**0.5%**	**0.7%**	**1.4%**
Transportation									
	Public Road	29	44	44	44	1.7%	2.6%	2.6%	2.6%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**29**	**44**	**44**	**44**	**1.7%**	**2.6%**	**2.6%**	**2.6%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	39	85	0.0%	0.0%	2.7%	5.9%	0.0%	2.7%	3.2%	5.9%
	Pivot	0	0	24	97	0.0%	0.0%	1.6%	6.7%	0.0%	1.6%	5.1%	6.7%
	Flood	63	167	0	9	4.3%	11.4%	0.0%	0.6%	7.2%	-11.4%	0.6%	-3.7%
	Totals	**63**	**167**	**63**	**190**	**4.3%**	**11.4%**	**4.3%**	**13.2%**	**7.2%**	**-7.1%**	**8.8%**	**8.9%**

Non-Irrigated

Multi-Use	1,341	1,287	1,354	1,236	91.1%	88.1%	93.1%	85.7%	-3.0%	5.0%	-7.4%	-5.5%
Hay/Pasture	68	7	37	17	4.6%	0.5%	2.6%	1.2%	-4.1%	2.1%	-1.4%	-3.4%
Totals	**1,408**	**1,294**	**1,392**	**1,253**	**95.7%**	**88.6%**	**95.7%**	**86.8%**	**-7.2%**	**7.1%**	**-8.8%**	**-8.9%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	0.0	5.5	25.0	0.0	**30.5**
Acres/Valley Mile	0.0	1.7	7.6	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.00	0.04%	0.10	0.00	0.02	0.07

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Yellowstone River Reach Narratives

Reach PC5

County	Park	**Upstream River Mile**	543.2
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	539.4
General Location	Hwy 89 Br. to Big Creek	**Length**	3.80 mi (6.12 km)

General Comments

Narrative Summary

From the Highway 89 Bridge downstream to Big Creek, Reach PC5 is the first notably dynamic reach below Gardiner, with high rates of bank movement and a relatively high density of side channels and islands. In 2001, there were almost four miles of active side channel in the reach, although one 3,500-foot long channel on the west side of the river has been blocked by a dike. This dike does appear to have a culvert in it, keeping the channel somewhat accessible. In addition to side channel blockages, this reach has been impacted by over 5,000 feet of bank armor, most of which is rock riprap. One section of riprap that was about 150 feet long when constructed has been flanked and is now in the middle of the river. Since the rock was flanked, the river has migrated over 100 feet behind the old armor.

Similar to other reaches in Park County, the extent of flood irrigation has dropped in the reach since 1950, and the amount of sprinkler and pivot irrigation has increased. Reach PC5 has seen a net expansion of about 150 acres of irrigated lands since 1950, with most of the expansion into pivot. There has also been 100 acres of exurban development in Reach PC5 since 1950. There is one boat ramp at RM 542.5 at the Point of Rocks Fishing Access.

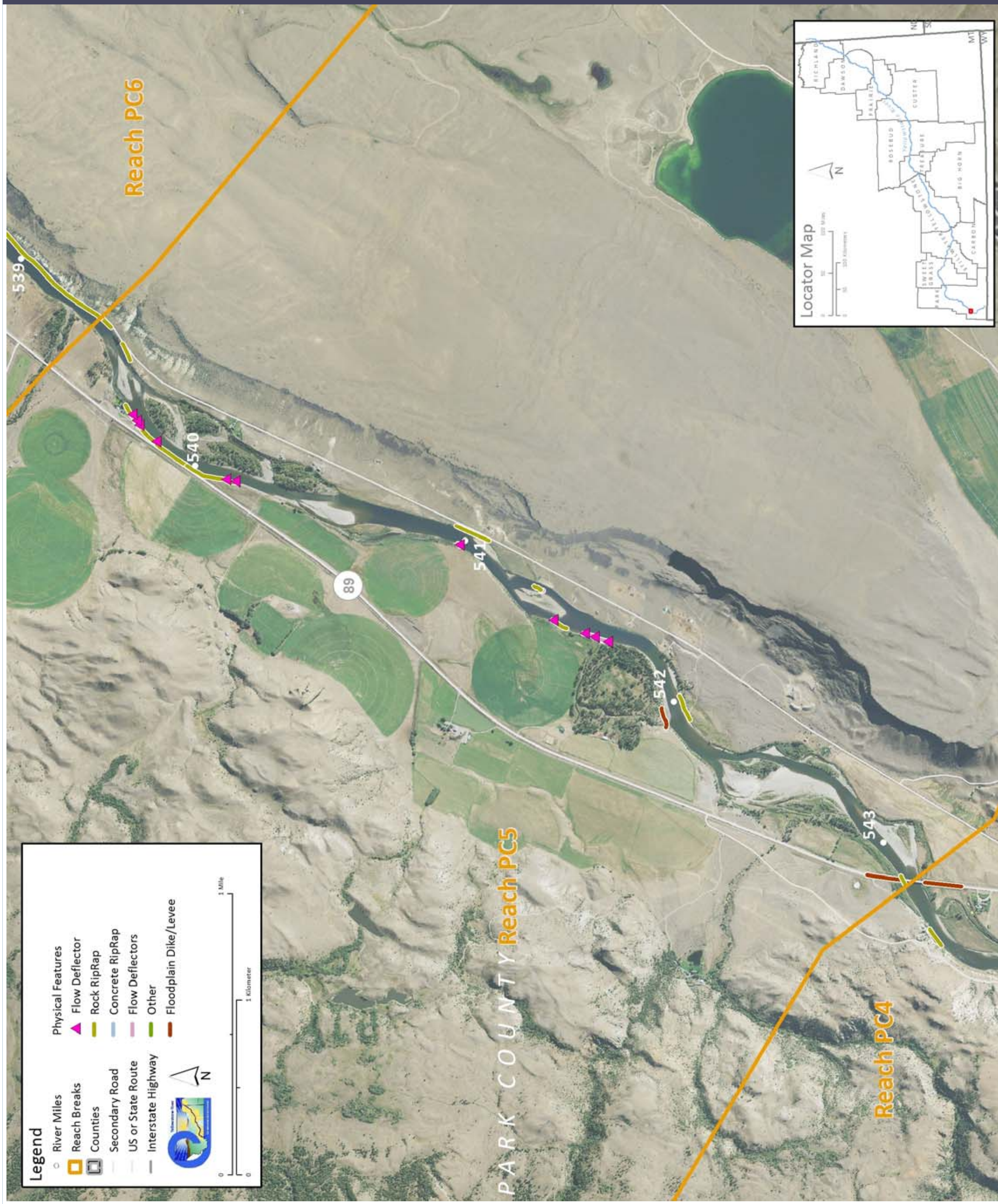
The influence of irrigation on streamflow is small but evident in Reach PC5. When gage data are extrapolated to reaches based on drainage area, Reach PC5 shows a 100 cfs reduction in the 2-year flood under developed conditions. This is a 0.5 percent reduction in the total flow of 19,000 cfs.

This area of the upper Yellowstone River basin experienced three severe floods in the last 20 years. The largest floods were in 1996 and 1997, when the 32,200 cfs peak flow measured at the Corwin Springs gage exceeded a 100-year flood for those two years in a row. The 1974 and 2011 floods were major as well, with both events exceeding 30,000 cfs. The Corwin Springs gage is located upstream of Reach PC5 at the Corwin Springs Bridge.

CEA-Related observations in Reach PC5 include:
•Blockage of a 3,500feet-long side channel by a dike which may have a culvert
•Flanking of rock riprap and accelerated erosion behind
•Net expansion of irrigated lands

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC5 include:
•Side Channel Restoration at RM 542
•Removal of flanked bank armor at RM 541.4

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Corwin Springs

Flood History

Year	Date	Flow on Date	Return Interval
1927	Jun 27	25,000	10-25 yr
1971	Jun 23	25,200	10-25 yr
1928	May 26	25,300	10-25 yr
1911	Jun 13	25,800	10-25 yr
2010	Jun 5	26,000	10-25 yr
2011	Jun 30	30,300	50-100 yr
1974	Jun 17	30,900	50-100 yr
1918	Jun 14	32,000	50-100 yr
1997	Jun 6	32,200	>100-yr
1996	Jun 10	32,200	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6192500	1619500
Location	Livingston	
Period of Record	1929-2015	
Distance To (miles)	32.8	

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,560	19,100	24,000	27,100	33,400	36,000	41,900	1,280	1,760
Regulated	9,500	19,000	23,900	27,000	33,400	36,000	41,900	1,260	1,680
% Change	-0.63%	-0.52%	-0.42%	-0.37%	0.00%	0.00%	0.00%	-1.56%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	6/27/2009	Color	1-meter pixels	6192500	15200
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	
2013	NAIP	08/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

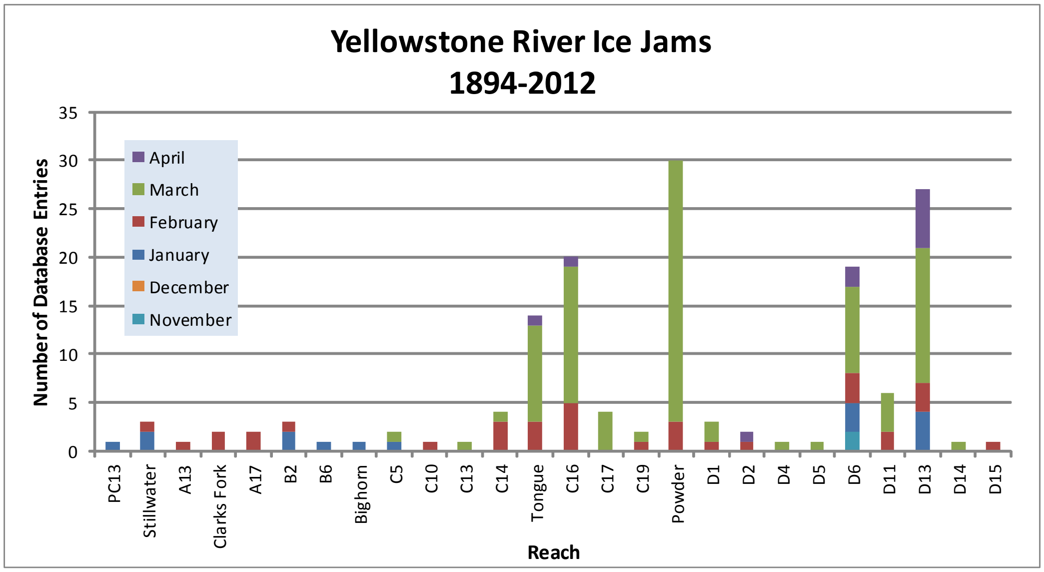
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	4,572	11.3%	4,372	10.8%	-201
	Flow Deflectors	707	1.8%	645	1.6%	-62
	Between Flow Deflectors	368	0.9%	348	0.9%	-20
	Feature Type Totals	**5,647**	**14.0%**	**5,365**	**13.3%**	**-282**
Floodplain Control						
	Floodplain Dike/Levee	1,023	2.5%	1,023	2.5%	0
	Feature Type Totals	**1,023**	**2.5%**	**1,023**	**2.5%**	**0**
	Reach Totals	**6,670**	**16.5%**	**6,388**	**15.8%**	**-282**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	20,497	10,881	1.53	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	20,180	20,151	2.00	1950 to 2001:	30.55%
Change 1950 - 2001	**-317**	**9,270**	**0.47**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	3,503

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
157	313	384	25	6%	0	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	4	0.9%
RipRap/Flow Deflectors			
	Public Road	6	1.5%
	Irrigated	9	2.2%
RipRap			
	Exurban Residential	1	0.4%
Dike/Levee			
	Non-Irrigated	3	0.8%
	Totals	**22**	**5.8%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
0.0	3.2	2.4	20.1	2.7

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	0	10	26	14	0.0%	0.8%	2.0%	1.0%
	Totals	**0**	**10**	**26**	**14**	**0.0%**	**0.8%**	**2.0%**	**1.0%**
Agricultural Land									
	Non-Irrigated	806	895	781	557	61.3%	68.0%	59.3%	42.4%
	Irrigated	188	100	102	335	14.3%	7.6%	7.8%	25.5%
	Totals	**995**	**995**	**883**	**893**	**75.6%**	**75.6%**	**67.1%**	**67.8%**
Channel									
	Channel	287	252	253	258	21.8%	19.1%	19.3%	19.6%
	Totals	**287**	**252**	**253**	**258**	**21.8%**	**19.1%**	**19.3%**	**19.6%**
ExUrban									
	ExUrban Other	0	7	20	20	0.0%	0.6%	1.5%	1.5%
	ExUrban Undeveloped	0	0	6	14	0.0%	0.0%	0.5%	1.0%
	ExUrban Industrial	0	0	7	7	0.0%	0.0%	0.5%	0.5%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	3	71	62	0.0%	0.2%	5.4%	4.7%
	Totals	**0**	**11**	**104**	**102**	**0.0%**	**0.8%**	**7.9%**	**7.8%**
Transportation									
	Public Road	35	49	49	49	2.6%	3.7%	3.7%	3.7%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**35**	**49**	**49**	**49**	**2.6%**	**3.7%**	**3.7%**	**3.7%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	88	74	0.0%	0.0%	10.0%	8.3%	0.0%	10.0%	-1.7%	8.3%
	Pivot	0	0	0	222	0.0%	0.0%	0.0%	24.9%	0.0%	0.0%	24.9%	24.9%
	Flood	188	100	14	39	18.9%	10.1%	1.6%	4.3%	-8.9%	-8.5%	2.8%	-14.6%
	Totals	**188**	**100**	**102**	**335**	**18.9%**	**10.1%**	**11.6%**	**37.6%**	**-8.9%**	**1.5%**	**26.0%**	**18.6%**

Non-Irrigated													
	Multi-Use	767	806	396	366	77.1%	81.0%	44.9%	41.0%	3.9%	-36.1%	-3.9%	-36.1%
	Hay/Pasture	39	89	384	191	3.9%	8.9%	43.5%	21.4%	5.0%	34.6%	-22.1%	17.5%
	Totals	**806**	**895**	**781**	**557**	**81.1%**	**89.9%**	**88.4%**	**62.4%**	**8.9%**	**-1.5%**	**-26.0%**	**-18.6%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	0.0	26.4	34.0	0.0	**60.4**
Acres/Valley Mile	0.0	7.4	9.6	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.11	0.06%	0.20	0.00	0.00	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County	Park	**Upstream River Mile**	539.4
Classification	CM: Confined meandering	**Downstream River Mile**	535
General Location	Big Creek to Six Mile Cr	**Length**	4.40 mi (7.08 km)

General Comments

Narrative Summary

Reach PC6 is 4.4 miles long, extending from the mouth of Big Creek to the mouth of Six Mile Creek. The reach has a fairly narrow riparian corridor and Channel Migration Zone (CMZ), indicating low rates of channel movement. Over two miles of the bankline in Reach PC6 are armored, by both rock riprap (7,371 feet) and flow deflectors (3,278 feet). Over 20 percent of the total bankline in this reach is armored, and all of that armor was in place in 2001. The armor protects both exurban and irrigated lands.

The amount of flood irrigated lands in Reach PC6 has dropped by one half since 1950 (200 acre reduction), and there has been commensurate development into pivot (85 acres) and sprinkler (93 acres) during that time. The overall footprint of agricultural lands within Reach PC6 has dropped by about 500 acres, with 450 of those acres converting to exurban development. About 11 acres of irrigated land in Reach PC6 are within the Channel Migration Zone. As the CMZ is quite narrow in this reach, it indicates that these irrigated lands extend essentially to the streambank. There is one boat ramp on the right bank at RM 536.8.

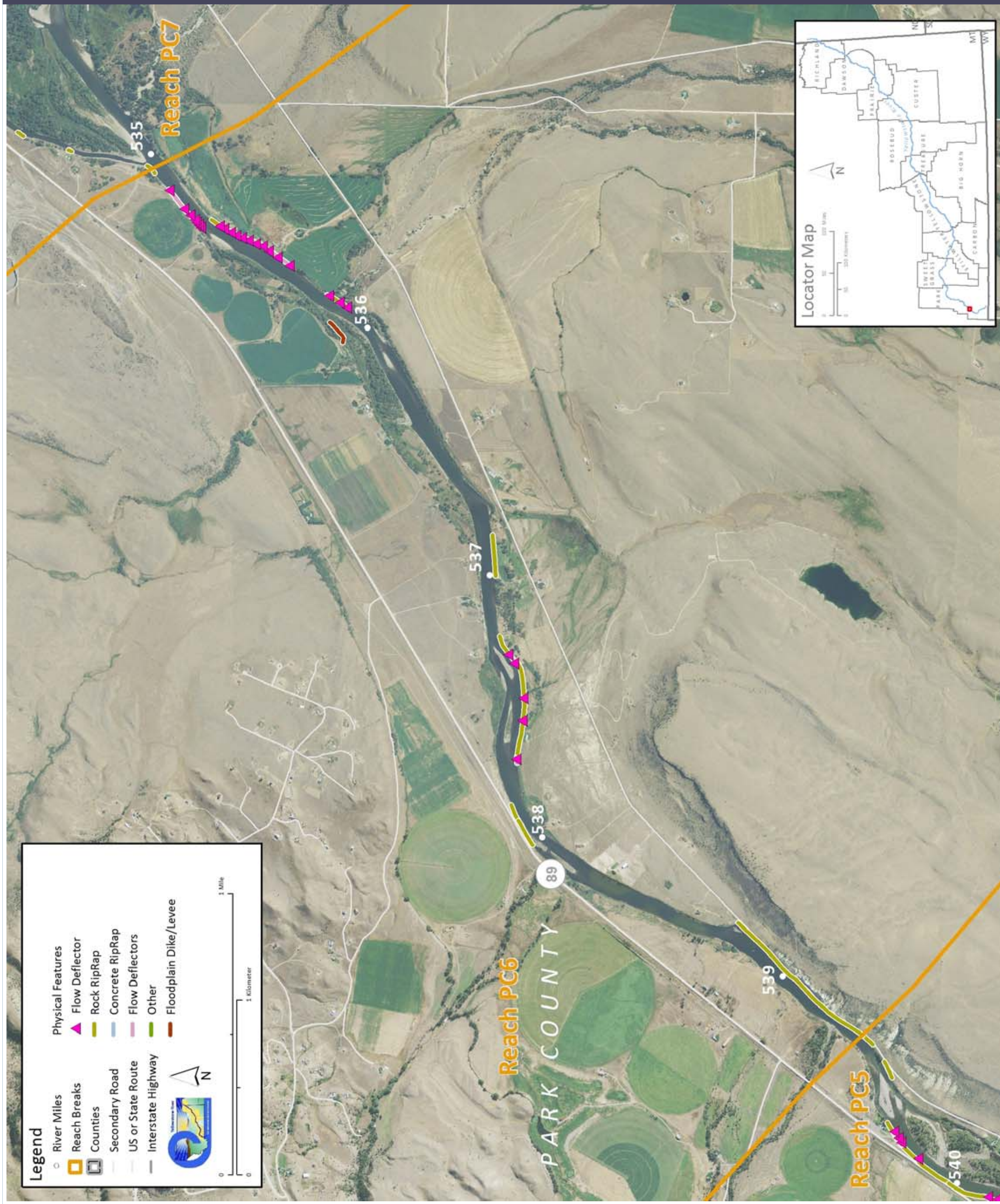
This area of the upper Yellowstone River basin experienced three severe floods in the last 20 years. The largest floods were in 1996 and 1997, when the 32,200 cfs peak flow measured at the Corwin Springs gage exceeded a 100-year flood for those two years in a row. The 1974 and 2011 floods were major as well, with both events exceeding 30,000 cfs. The Corwin Springs gage is located upstream of Reach PC6 at the Corwin Springs Bridge.

A hydrologic evaluation of flow depletions in the reach indicates that flow alterations over the last century have been minimal in this reach. Flow reductions due to human influences are estimated to be less than 2 percent for both high and low flows.

CEA-Related observations in Reach PC6 include:
•Conversion of agricultural land to exurban development
•Agricultural and exurban development close to the active channel within the CMZ

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC6 include:
•CMZ Management due to extensive encroachment of irrigated lands to edge of river.

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Corwin Springs

Flood History

Year	Date	Flow on Date	Return Interval
1927	Jun 27	25,000	10-25 yr
1971	Jun 23	25,200	10-25 yr
1928	May 26	25,300	10-25 yr
1911	Jun 13	25,800	10-25 yr
2010	Jun 5	26,000	10-25 yr
2011	Jun 30	30,300	50-100 yr
1974	Jun 17	30,900	50-100 yr
1918	Jun 14	32,000	50-100 yr
1997	Jun 6	32,200	>100-yr
1996	Jun 10	32,200	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6192500	6191500
Location	Livingston	Corwin Springs
Period of Record	1929-2015	1890-2012
Distance To (miles)	28.4	17.8

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,560	19,100	24,000	27,100	33,400	36,000	41,900	1,310	1,760
Regulated	9,500	19,000	23,900	27,000	33,400	36,000	41,900	1,290	1,680
% Change	-0.63%	-0.52%	-0.42%	-0.37%	0.00%	0.00%	0.00%	-1.53%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/22/2009	Color	1-meter pixels	6192500	6990
2009	NAIP	6/27/2009	Color	1-meter pixels	6192500	15200
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	
2013	NAIP	08/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

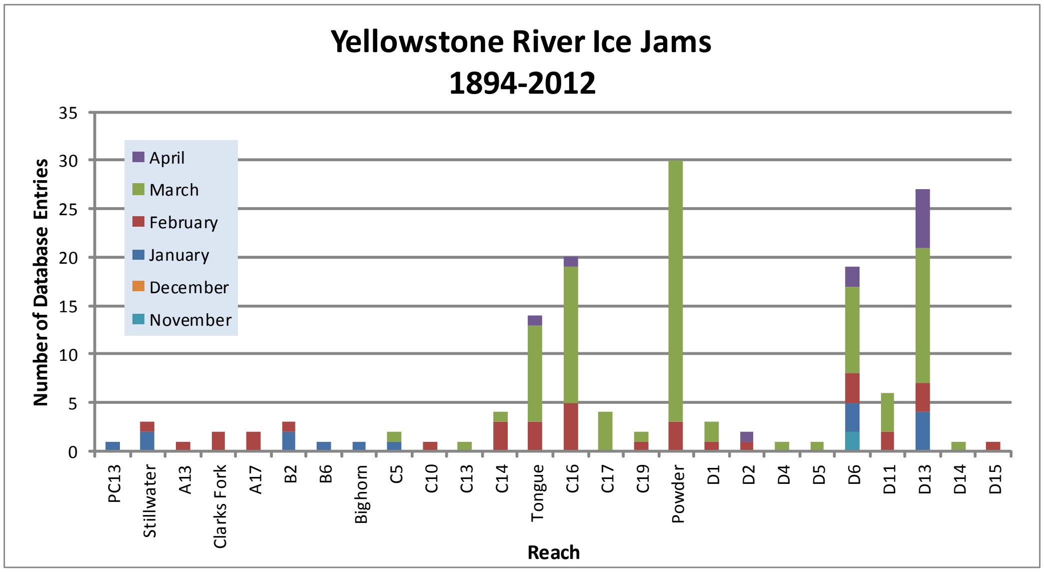
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	7,371	16.2%	7,371	16.2%	0
	Flow Deflectors	1,685	3.7%	1,685	3.7%	0
	Between Flow Deflectors	1,593	3.5%	1,593	3.5%	0
	Feature Type Totals	**10,649**	**23.4%**	**10,649**	**23.4%**	**0**
Floodplain Control						
	Floodplain Dike/Levee	477	1.1%	477	1.1%	0
	Feature Type Totals	**477**	**1.1%**	**477**	**1.1%**	**0**
	Reach Totals	**11,126**	**24.5%**	**11,126**	**24.5%**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	22,711	4,503	1.20	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	22,709	4,579	1.20	1950 to 2001:	0.28%
Change 1950 - 2001	**-2**	**76**	**0.00**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
55	110	275	24	9%	12	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Other Infrastructure	2	0.5%
	Exurban Residential	11	4.0%
RipRap			
	Public Road	2	0.8%
Flow Deflectors			
	Irrigated	8	2.7%
Dike/Levee			
	Non-Irrigated	1	0.4%
	Totals	**24**	**8.4%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
10.6	0.0	0.7	29.0	1.8

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	17	68	75	86	1.1%	4.4%	4.9%	5.6%
	Totals	**17**	**68**	**75**	**86**	**1.1%**	**4.4%**	**4.9%**	**5.6%**
Agricultural Land									
	Non-Irrigated	869	800	903	415	56.7%	52.2%	58.9%	27.1%
	Irrigated	409	430	205	355	26.7%	28.1%	13.4%	23.2%
	Totals	**1,278**	**1,230**	**1,107**	**770**	**83.4%**	**80.3%**	**72.3%**	**50.3%**
Channel									
	Channel	192	188	188	188	12.5%	12.3%	12.3%	12.3%
	Totals	**192**	**188**	**188**	**188**	**12.5%**	**12.3%**	**12.3%**	**12.3%**
ExUrban									
	ExUrban Other	0	0	0	3	0.0%	0.0%	0.0%	0.2%
	ExUrban Undeveloped	4	4	16	233	0.3%	0.3%	1.0%	15.2%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	104	211	0.0%	0.0%	6.8%	13.7%
	Totals	**4**	**4**	**120**	**446**	**0.3%**	**0.3%**	**7.8%**	**29.1%**
Transportation									
	Public Road	41	42	42	42	2.7%	2.7%	2.7%	2.7%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**41**	**42**	**42**	**42**	**2.7%**	**2.7%**	**2.7%**	**2.7%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	93	93	0.0%	0.0%	8.4%	12.0%	0.0%	8.4%	3.7%	12.0%
	Pivot	0	0	49	85	0.0%	0.0%	4.4%	11.0%	0.0%	4.4%	6.6%	11.0%
	Flood	409	430	63	178	32.0%	35.0%	5.7%	23.1%	3.0%	-29.3%	17.4%	-8.9%
	Totals	**409**	**430**	**205**	**355**	**32.0%**	**35.0%**	**18.5%**	**46.1%**	**3.0%**	**-16.5%**	**27.6%**	**14.1%**

Non-Irrigated

Multi-Use	849	761	571	272	66.4%	61.8%	51.6%	35.3%	-4.6%	-10.3%	-16.2%	-31.1%
Hay/Pasture	20	39	332	143	1.6%	3.2%	29.9%	18.6%	1.7%	26.7%	-11.4%	17.0%
Totals	**869**	**800**	**903**	**415**	**68.0%**	**65.0%**	**81.5%**	**53.9%**	**-3.0%**	**16.5%**	**-27.6%**	**-14.1%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	1.0	62.6	13.6	0.0	**77.2**
Acres/Valley Mile	0.2	15.3	3.3	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.01	0.15%	0.66	0.00	0.00	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County	Park	**Upstream River Mile**	535
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	529
General Location	Six Mile Cr to Grey Owl	**Length**	6.00 mi (9.66 km)

General Comments

Narrative Summary

Reach PC7 extends from the mouth of Six Mile Creek to the Grey Owl fishing access site. It is six miles long and is classified as a Partially Confined Anabranching (PCA) channel type. This indicates that the reach supports side channels and wooded islands, and intermittently flows along the edge of the stream corridor. The relatively complex reach type is evidenced by the relative broad Channel Migration Zone (CMZ) footprint, which is typically about 1500 to 2500 feet wide in this reach. In comparison, Reach PC6 just upstream has a CMZ that is typically about 500 feet wide. There are a total of 1,171 acres of stream corridor within the CMZ in Reach PC7. About 6 percent of that area has been restricted by bank armor.

Reach PC7 has over 8,800 feet of rock riprap and 550 feet of flow deflectors, which collectively armors about 15 percent of the total bankline. Of those 9,350 feet of armor, about 350 feet were constructed since 2001. Since 1950, one side channel that is 2,950 feet long was blocked by a dike at RM 532. This isolated channel is located just upstream of the Emigrant Bridge on the east floodplain, and has been identified as a potential side channel restoration area. In the upstream portion of the reach at RM 534, the Park Branch Canal diverts water from a long side channel that has been active since at least the 1950s.

Land use conversions in Reach PC7 have seen a reduction in flood irrigation that has been accompanied by about 67 acres of development of sprinkler and pivot irrigation systems. That said, this reach has experienced major exurban growth, from 0 acres in 1950 to 298 acres in 2011. Most of that growth reflects rural subdivision development on the glacial outwash terraces above the active stream corridor. There is one boat ramp on the right bank just above the Emigrant Bridge at the Emigrant Fishing Access Site, and just below the bridge, there is a ~72 acre fishing access site without boating facilities on the west side of the river (Emigrant West).

Reach PC7 contains over 200 acres of emergent wetlands, many of which appear to be associated with groundwater seepage from the base of the glacial terraces on the east side of the river, and ditch seepage on the west side of the river. These areas tend to be utilized as non-irrigated hay/pasture ground.

About 1.5 acres of Russian olive have been mapped in Reach PC7, which is a dramatic increase relative to upstream reaches.

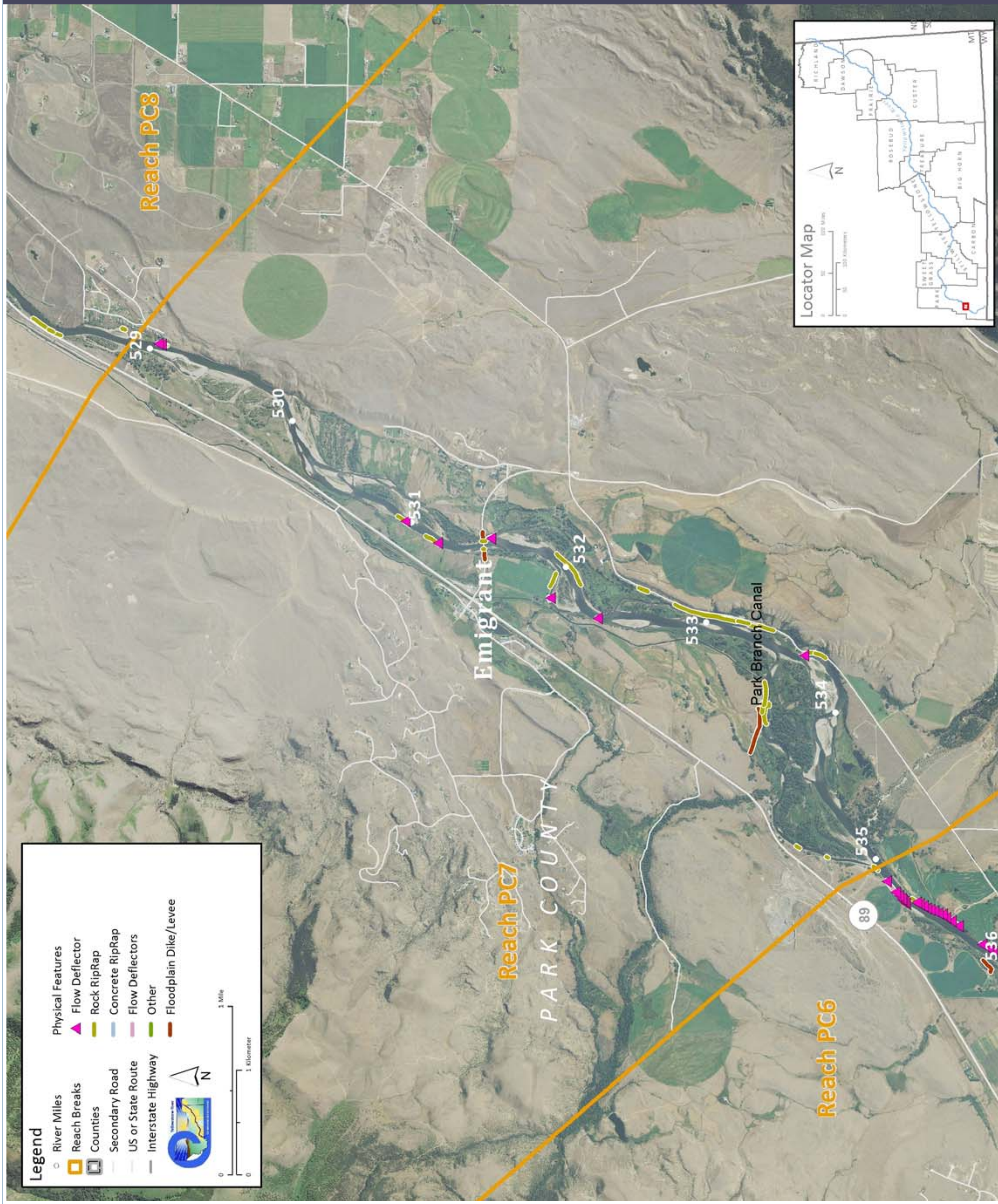
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,340 cfs to 1,320 cfs with human development, a reduction of 1.5 percent.

CEA-Related observations in Reach PC7 include:
•Conversion of agricultural land to exurban development
•Post-1950s side channel blockage with identified restoration potential
•Sharp increase in Russian olive extent relative to upstream reaches

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC7 include:
•Side Channel Restoration at RM 532R.
•Diversion Infrastructure Management at Park Branch Canal, RM 535.5
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Corwin Springs

Flood History

Year	Date	Flow on Date	Return Interval
1927	Jun 27	25,000	10-25 yr
1971	Jun 23	25,200	10-25 yr
1928	May 26	25,300	10-25 yr
1911	Jun 13	25,800	10-25 yr
2010	Jun 5	26,000	10-25 yr
2011	Jun 30	30,300	50-100 yr
1974	Jun 17	30,900	50-100 yr
1918	Jun 14	32,000	50-100 yr
1997	Jun 6	32,200	>100-yr
1996	Jun 10	32,200	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6192500	6191500
Location	Livingston	Corwin Springs
Period of Record	1929-2015	1890-2012
Distance To (miles)	22.4	22.2

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,560	19,100	24,000	27,100	33,400	36,000	41,900	1,340	1,760
Regulated	9,500	19,000	23,900	27,000	33,400	36,000	41,900	1,320	1,680
% Change	-0.63%	-0.52%	-0.42%	-0.37%	0.00%	0.00%	0.00%	-1.49%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/28/2005	color	1-meter pixels	6192500	2210
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/22/2009	Color	1-meter pixels	6192500	6990
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	
2013	NAIP	08/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

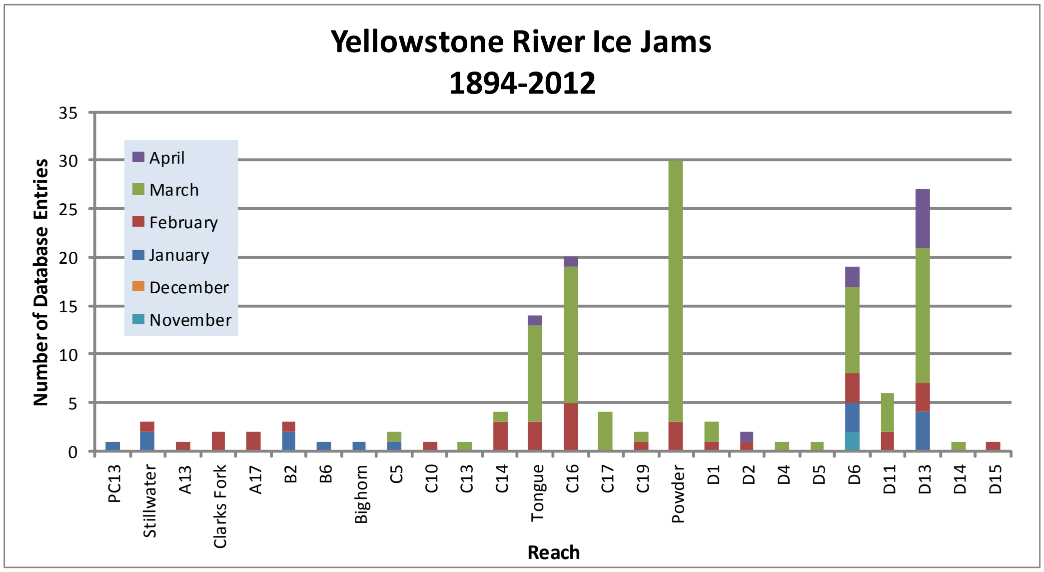
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	8,540	13.1%	8,841	13.6%	301
	Flow Deflectors	502	0.8%	556	0.9%	54
	Feature Type Totals	**9,042**	**13.9%**	**9,396**	**14.4%**	**355**
Floodplain Control						
	Floodplain Dike/Levee	2,005	3.1%	2,005	3.1%	0
	Feature Type Totals	**2,005**	**3.1%**	**2,005**	**3.1%**	**0**
	Reach Totals	**11,047**	**17.0%**	**11,401**	**17.5%**	**355**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	34,130	29,472	1.86	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	32,556	41,507	2.27	1950 to 2001:	22.08%
Change 1950 - 2001	**-1,574**	**12,035**	**0.41**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	2,950

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
194	388	1,171	74	6%	39	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Public Road	0	0.0%
RipRap			
	Non-Irrigated	36	2.9%
	Irrigated	6	0.5%
	Exurban Undevelope	0	0.0%
	Exurban Residential	2	0.2%
	Canal	18	1.5%
Dike/Levee			
	Public Road	12	1.0%
	Totals	**74**	**6.1%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
10.0	11.6	0.0	16.0	3.5

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	33	33	33	33	1.2%	1.2%	1.2%	1.2%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	28	54	49	62	1.0%	2.0%	1.8%	2.3%
	Totals	**61**	**87**	**82**	**95**	**2.2%**	**3.2%**	**3.0%**	**3.5%**
Agricultural Land									
	Non-Irrigated	1,487	1,430	1,282	1,271	54.5%	52.4%	47.0%	46.6%
	Irrigated	415	315	265	237	15.2%	11.6%	9.7%	8.7%
	Totals	**1,902**	**1,746**	**1,547**	**1,509**	**69.7%**	**64.0%**	**56.7%**	**55.3%**
Channel									
	Channel	701	721	766	767	25.7%	26.5%	28.1%	28.1%
	Totals	**701**	**721**	**766**	**767**	**25.7%**	**26.5%**	**28.1%**	**28.1%**
ExUrban									
	ExUrban Other	0	1	3	3	0.0%	0.1%	0.1%	0.1%
	ExUrban Undeveloped	3	0	5	13	0.1%	0.0%	0.2%	0.5%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	21	30	30	0.0%	0.8%	1.1%	1.1%
	ExUrban Residential	22	94	236	251	0.8%	3.4%	8.7%	9.2%
	Totals	**25**	**116**	**274**	**298**	**0.9%**	**4.3%**	**10.0%**	**10.9%**
Transportation									
	Public Road	39	57	59	59	1.4%	2.1%	2.1%	2.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**39**	**57**	**59**	**59**	**1.4%**	**2.1%**	**2.1%**	**2.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	50	50	0.0%	0.0%	3.3%	3.3%	0.0%	3.3%	0.1%	3.3%
	Pivot	0	0	0	17	0.0%	0.0%	0.0%	1.1%	0.0%	0.0%	1.1%	1.1%
	Flood	415	315	214	170	21.8%	18.1%	13.9%	11.3%	-3.7%	-4.2%	-2.6%	-10.5%
	Totals	**415**	**315**	**265**	**237**	**21.8%**	**18.1%**	**17.1%**	**15.7%**	**-3.7%**	**-0.9%**	**-1.4%**	**-6.1%**

Non-Irrigated

Multi-Use	928	1,373	1,116	1,088	48.8%	78.6%	72.1%	72.1%	29.8%	-6.5%	0.0%	23.3%
Hay/Pasture	559	57	167	184	29.4%	3.3%	10.8%	12.2%	-26.1%	7.5%	1.4%	-17.2%
Totals	**1,487**	**1,430**	**1,282**	**1,271**	**78.2%**	**81.9%**	**82.9%**	**84.3%**	**3.7%**	**0.9%**	**1.4%**	**6.1%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	12.1	203.9	112.5	0.0	**328.5**
Acres/Valley Mile	2.1	36.0	19.9	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	1.47	0.16%	0.81	0.15	0.14	0.02

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County	Park	**Upstream River Mile**	529
Classification	CM: Confined meandering	**Downstream River Mile**	516.3
General Location	Grey Owl to just below Mallard's Rest	**Length**	12.70 mi (20.44 km)

General Comments

Narrative Summary

Reach PC8 extends from the Grey Owl fishing access site to just below Mallard's Rest. It is almost 13 miles long and is classified as confined meandering, indicating that it has somewhat of a sinuous planform but is largely confined by older terraces or bedrock. This is a remarkably stable reach that shows little evidence of channel migration. Even though migration rates are low, approximately 8 percent of the bankline has been armored by 7,500 feet of rock riprap and 2,760 feet of flow deflectors. About 3,200 feet of that armor was constructed since 2001.

Similar to other reaches in Park County, the extent of flood irrigation has dropped in the reach since 1950, and the amount of sprinkler and pivot irrigation has increased proportionately. There has also been a major expansion of exurban land uses in the reach from 14 acres in 1950 to 1,433 acres in 2011. By comparison, 220 acres are in flood, 170 acres in sprinkler, and 1,014 acres in pivot irrigation. The relative expansion of pivot irrigation in this reach is large compared to the rest of the Paradise Valley. About 30 acres of irrigated land are located within the Channel Migration Zone, and 14 of those are under pivot. In one case (RM 519.5) a pivot occupies the entire core of a meander bend.

The popularity of recreational fishing in this reach is exemplified by the seven boat ramps identified in this 13 mile stretch of river. Fishing Access Sites in this reach include Grey Owl, Paradise, Lock Leven, and Mallard's Rest.

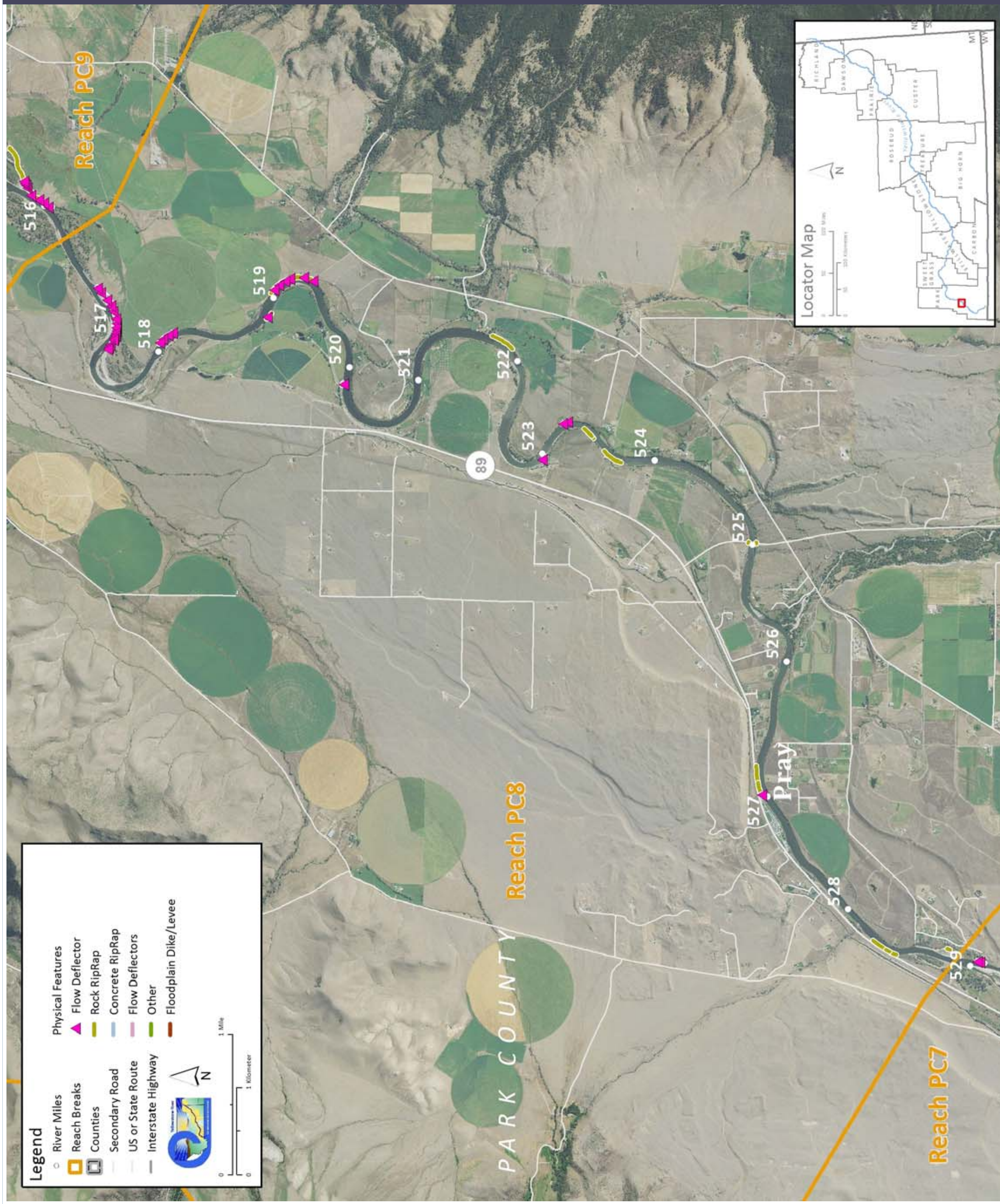
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events now considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,470 cfs to 1,430 cfs with human development, a reduction of 2.7 percent.

CEA-Related observations in Reach PC8 include:
•Major expansion from flood irrigation to pivot
•Conversion of agricultural land to exurban development
•Extensive armoring in naturally stable reach

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC8 include:
•Channel Migration Zone (CMZ) management

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6192500	1619500
Location	Livingston	
Period of Record	1929-2015	
Distance To (miles)	9.7	

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,820	19,500	24,600	27,800	34,200	36,800	42,800	1,470	1,760
Regulated	9,760	19,400	24,500	27,700	34,100	36,800	42,800	1,430	1,680
% Change	-0.61%	-0.51%	-0.41%	-0.36%	-0.29%	0.00%	0.00%	-2.72%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/28/2005	color	1-meter pixels	6192500	2210
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/23/2009	Color	1-meter pixels	6192500	6770
2009	NAIP	7/22/2009	Color	1-meter pixels	6192500	6990
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

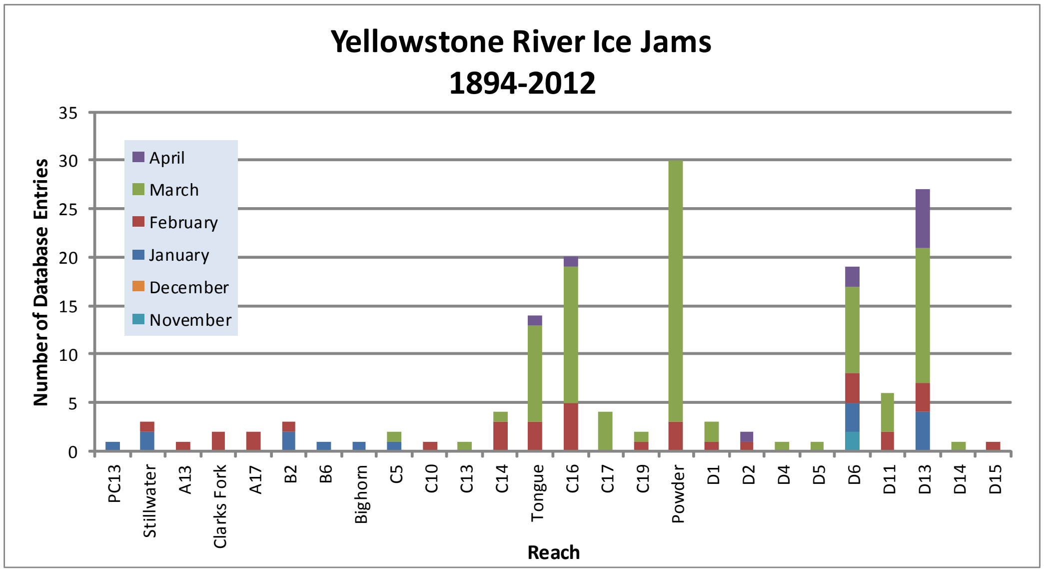
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	4,458	3.3%	7,494	5.6%	3,036
	Flow Deflectors	1,560	1.2%	1,603	1.2%	42
	Between Flow Deflectors	1,034	0.8%	1,155	0.9%	121
	Feature Type Totals	**7,052**	**5.3%**	**10,251**	**7.7%**	**3,199**
	Reach Totals	**7,052**	**5.3%**	**10,251**	**7.7%**	**3,199**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	66,249	3,175	1.05	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	66,558	3,657	1.05	1950 to 2001:	0.67%
Change 1950 - 2001	**309**	**482**	**0.01**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
75	150	765	14	2%	39	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Non-Irrigated	2	0.2%
RipRap			
	Public Road	6	0.7%
Flow Deflectors			
	Non-Irrigated	4	0.5%
	Irrigated	2	0.3%
	Exurban Residential	1	0.1%
	Totals	**14**	**1.8%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
11.3	5.1	14.0	101.0	2.7

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	41	41	41	41	0.8%	0.8%	0.8%	0.8%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	32	60	61	59	0.6%	1.2%	1.2%	1.2%
	Totals	**73**	**101**	**102**	**100**	**1.5%**	**2.0%**	**2.1%**	**2.0%**
Agricultural Land									
	Non-Irrigated	2,966	3,114	1,985	1,432	59.9%	62.9%	40.1%	28.9%
	Irrigated	1,369	978	1,436	1,407	27.7%	19.8%	29.0%	28.4%
	Totals	**4,335**	**4,092**	**3,421**	**2,838**	**87.6%**	**82.7%**	**69.1%**	**57.3%**
Channel									
	Channel	511	493	510	511	10.3%	10.0%	10.3%	10.3%
	Totals	**511**	**493**	**510**	**511**	**10.3%**	**10.0%**	**10.3%**	**10.3%**
ExUrban									
	ExUrban Other	0	36	39	39	0.0%	0.7%	0.8%	0.8%
	ExUrban Undeveloped	0	0	68	416	0.0%	0.0%	1.4%	8.4%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	14	164	743	978	0.3%	3.3%	15.0%	19.8%
	Totals	**14**	**200**	**850**	**1,433**	**0.3%**	**4.0%**	**17.2%**	**29.0%**
Transportation									
	Public Road	17	63	64	64	0.3%	1.3%	1.3%	1.3%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**17**	**63**	**64**	**64**	**0.3%**	**1.3%**	**1.3%**	**1.3%**
Urban									
	Urban Other	0	2	2	3	0.0%	0.0%	0.0%	0.1%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**2**	**2**	**3**	**0.0%**	**0.0%**	**0.0%**	**0.1%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	110	171	0.0%	0.0%	3.2%	6.0%	0.0%	3.2%	2.8%	6.0%
	Pivot	0	0	760	1,014	0.0%	0.0%	22.2%	35.7%	0.0%	22.2%	13.5%	35.7%
	Flood	1,369	978	566	221	31.6%	23.9%	16.5%	7.8%	-7.7%	-7.4%	-8.8%	-23.8%
	Totals	**1,369**	**978**	**1,436**	**1,407**	**31.6%**	**23.9%**	**42.0%**	**49.6%**	**-7.7%**	**18.1%**	**7.6%**	**18.0%**

Non-Irrigated

Multi-Use	2,863	2,626	1,663	1,361	66.0%	64.2%	48.6%	48.0%	-1.9%	-15.6%	-0.6%	-18.1%
Hay/Pasture	103	488	322	70	2.4%	11.9%	9.4%	2.5%	9.6%	-2.5%	-6.9%	0.1%
Totals	**2,966**	**3,114**	**1,985**	**1,432**	**68.4%**	**76.1%**	**58.0%**	**50.4%**	**7.7%**	**-18.1%**	**-7.6%**	**-18.0%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	3.3	43.2	1.6	0.0	**48.1**
Acres/Valley Mile	0.3	4.5	0.2	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.67	0.28%	2.26	0.01	0.12	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County	Park	**Upstream River Mile**	516.3
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	514.6
General Location	To Pine Creek	**Length**	1.70 mi (2.74 km)

General Comments

Narrative Summary

Reach PC9 extends from just below Mallard's Rest to Pine Creek. It is a partially confined anabranching reach type, indicating that it has side channels and wooded islands with some valley wall influence. Reach PC9 is one of the shortest reaches in the CEA study at 1.7 miles. It is a short, fairly anomalous section of river that extends upstream from the mouth of Pine Creek and Pine Creek Bridge. This reach is anomalous because of its rates of change over the past 20 years. This includes sediment deposition, severe bank erosion and avulsions. The reach is located just upstream of a "pinch point" in the valley that is created by a glacial outwash terrace on the west bank and the Pine Creek outwash fan on the right bank. The Pine Creek Bridge was built on this pinch point, which is a stable bridge location. Because of the constriction at the bridge, however, sediment transport patterns appear interrupted which has caused sediment deposition and unstable channel dynamics upstream. Much of this erosion appears to have happened between 1991 and 2005, suggesting that the 1996 and 1997 floods drove substantial channel change.

Reach PC9 showed an increase in bankfull channel area of over 30 acres between 1950 and 2001, which may reflect the impact of the 1996/1997 floods on channel form. Air photos from as recently as 1991 show a broad expanse of forested islands, whereas the 2005 and 2011 imagery show extensive open bars and active bank erosion. In places, erosion into islands since 1991 has exceeded 500 feet. This has been accompanied by an increase in side channel length of almost 7,000 feet in the reach as islands have been eroded and dissected.

In 2011, almost 3,000 feet of rock riprap lined the banks in Reach PC9, as well as 677 feet of flow deflectors. This represents almost 20 percent of the total bankline in the reach.

Similar to other reaches in Park County, the extent of flood irrigation has dropped in the reach since 1950, and the amount of sprinkler and pivot irrigation has increased somewhat proportionately. Exurban land uses in the reach have expanded from 0 acres in 1950 to 82 acres in 2011, and all of that development is on the east side of the river just upstream of Pine Creek Bridge. The dominant land use remains agriculture, however, with 27 acres in flood irrigation, 142 acres in sprinkler, and 93 acres in pivot. Another 300 acres are in non-irrigated agriculture. There are almost 100 acres of emergent wetlands in Reach PC9, reflecting a large wet meadow complex on the southeast side of the river.

This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events now considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,520 cfs to 1,470 cfs with human development, a reduction of 3.9 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC9 include:
•Major post-1995 changes in channel geomorphology upstream of natural constriction point.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC9 include:
•Channel Migration Zone (CMZ) management

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6192500	6191500
Location	Livingston	Corwin Springs
Period of Record	1929-2015	1890-2012
Distance To (miles)	8.0	40.9

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,820	19,500	24,600	27,800	34,200	36,800	42,800	1,520	1,760
Regulated	9,760	19,400	24,500	27,700	34,100	36,800	42,800	1,470	1,680
% Change	-0.61%	-0.51%	-0.41%	-0.36%	-0.29%	0.00%	0.00%	-3.29%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/23/2009	Color	1-meter pixels	6192500	6770
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

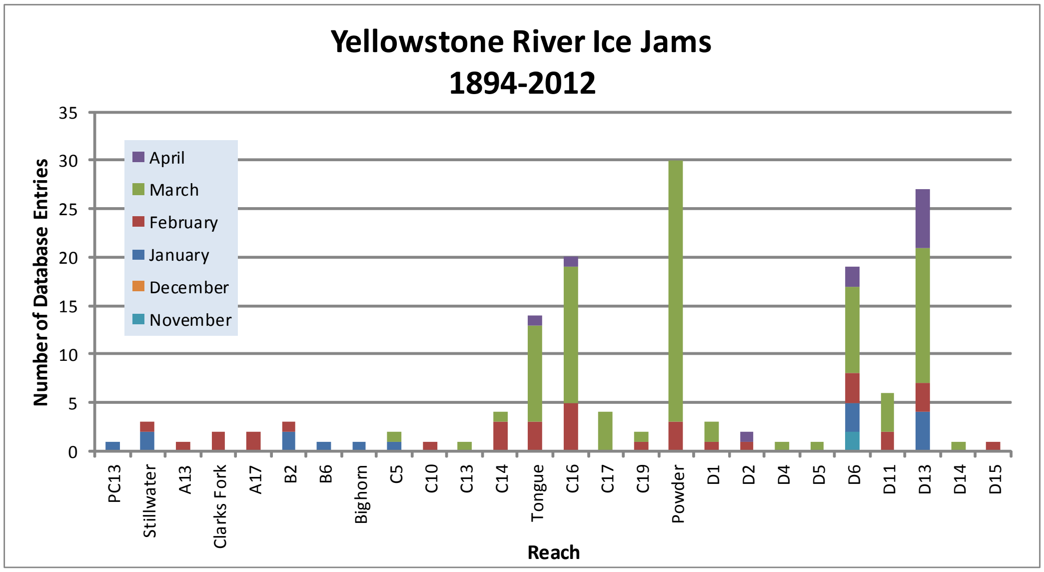
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	2,740	13.6%	2,894	14.4%	154
	Flow Deflectors	599	3.0%	599	3.0%	0
	Between Flow Deflectors	157	0.8%	79	0.4%	-79
	Feature Type Totals	**3,495**	**17.4%**	**3,571**	**17.7%**	**75**
	Reach Totals	**3,495**	**17.4%**	**3,571**	**17.7%**	**75**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	11,280	10,502	1.93	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	10,061	17,176	2.71	1950 to 2001:	40.20%
Change 1950 - 2001	**-1,219**	**6,674**	**0.78**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
183	365	341	36	10%	26	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Non-Irrigated	33	8.9%
RipRap			
	Public Road	1	0.4%
	Exurban Residential	3	0.8%
Flow Deflectors			
	Other Infrastructure	3	0.8%
	Totals	**40**	**11.0%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
0.9	2.7	0.0	11.3	0.6

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	4	20	43	39	0.4%	2.0%	4.4%	4.1%
	Totals	**4**	**20**	**43**	**39**	**0.4%**	**2.0%**	**4.4%**	**4.1%**
Agricultural Land									
	Non-Irrigated	558	422	268	353	57.6%	43.6%	27.7%	36.4%
	Irrigated	198	296	358	263	20.4%	30.6%	36.9%	27.1%
	Totals	**757**	**718**	**627**	**615**	**78.1%**	**74.1%**	**64.6%**	**63.5%**
Channel									
	Channel	204	227	229	229	21.0%	23.4%	23.6%	23.6%
	Totals	**204**	**227**	**229**	**229**	**21.0%**	**23.4%**	**23.6%**	**23.6%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	67	82	0.0%	0.0%	6.9%	8.4%
	Totals	**0**	**0**	**67**	**82**	**0.0%**	**0.0%**	**6.9%**	**8.4%**
Transportation									
	Public Road	5	5	4	4	0.5%	0.5%	0.4%	0.4%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**5**	**5**	**4**	**4**	**0.5%**	**0.5%**	**0.4%**	**0.4%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	211	142	0.0%	0.0%	33.6%	23.1%	0.0%	33.6%	-10.5%	23.1%
	Pivot	0	0	30	93	0.0%	0.0%	4.8%	15.2%	0.0%	4.8%	10.3%	15.2%
	Flood	198	296	117	27	26.2%	41.2%	18.7%	4.4%	15.0%	-22.5%	-14.4%	-21.8%
	Totals	**198**	**296**	**358**	**263**	**26.2%**	**41.2%**	**57.2%**	**42.7%**	**15.0%**	**15.9%**	**-14.5%**	**16.5%**

Non-Irrigated

Multi-Use	557	403	206	145	73.7%	56.2%	32.8%	23.6%	-17.5%	-23.3%	-9.3%	-50.1%
Hay/Pasture	1	19	63	208	0.2%	2.6%	10.0%	33.8%	2.4%	7.4%	23.8%	33.6%
Totals	**558**	**422**	**268**	**353**	**73.8%**	**58.8%**	**42.8%**	**57.3%**	**-15.0%**	**-15.9%**	**14.5%**	**-16.5%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	1.1	94.8	17.7	0.0	**113.6**
Acres/Valley Mile	0.6	55.2	10.3	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.12	0.18%	0.65	0.00	0.01	0.01

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County	Park	**Upstream River Mile**	514.6
Classification	PCM: Partially confined meandering	**Downstream River Mile**	511
General Location	To downstream of Deep Creek; Weeping wall, Jumpin	**Length**	3.60 mi (5.79 km)
General Comments			

Narrative Summary

Reach PC10 is extends from the Pine Creek Bridge to below the mouth of Deep Creek. The reach is approximately 3.5 miles long, extending from RM 511.0 to RM 514.5. This is an especially unique section of the Yellowstone River where spring creeks that parallel the channel support a nationally recognized cold water fishery. The reach is also semi-confined by very coarse grained glacial alluvial terraces. Sediment recruitment from the terraces drives bar formation, resulting in locally rapid bank migration, and in some cases, threats to the spring creeks. This was exemplified during the 1996/1997 floods, when the river migrated tens of feet into high glacial terraces, delivering vast amounts of gravel to the channel. At one location near the Deep Creek confluence, a home on a ~30 foot high glacial terrace was undermined and deliberately burnt down to prevent its collapse into the river. Just downstream of this site, rapid point bar growth drove westward channel migration towards a prized spring creek, which created a real risk of Yellowstone River avulsion into that channel. Efforts to prevent an avulsion included sediment removal from the rapidly enlarging point bar, bank protection, and construction of a long floodplain dike between the spring creek and the river. This single bendway experienced approximately 750 feet of migration between 1948 and 1999, which translates to an average migration rate of 14.7 feet per year.

Approximately 14 percent of the bankline is armored, primarily by rock riprap (3,753 feet) and flow deflectors (1,197 feet). Between 2001 and 2011, the net length of bank armor increased by 1,037 feet, although 50 feet of flow deflectors were eroded out during that time. There are also over two miles of floodplain dikes in the reach, most of which run parallel to the river to isolate the spring creeks. Several thousand feet of side channels have been blocked in Reach PC10; one large channel that was blocked prior to 1950 extends downstream for several thousand feet into Reach PC11. There is a high concentration of emergent wetlands in these abandoned side channels.

The total bankfull channel area in Reach PC10 increased from 151 acres in 1950 to 191 acres in 2001, suggesting channel enlargement, either due to floods or flow concentrations in the main channel due to side channel loss and diking.

Land uses in Reach PC10 include irrigated ground, multi-use (non-irrigated and undeveloped), and exurban residential development. Whereas in 1950 there were 512 acres under flood irrigation, by 2011 that had been reduced to 17 acres. The expansion of irrigation during that time included 136 acres of sprinkler, and another 56 acres of pivot irrigation. Most of the land, over 900 acres, is used as non-irrigated agricultural land. There has also been about 180 acres of exurban development in Reach PC10, much of which is part of the Jumping Rainbow Ranch downstream of Deep Creek. Some of this development, such as the location of the house that was undermined in 1997, is in the Channel Migration Zone. In the upstream portion the reach, a gravel pit on a large point bar (RM 513.8) encroaches into the Channel Migration Zone. Because of the extensive levee construction in the reach to protect spring creeks, 38 percent of the CMZ has been restricted from the natural CMZ footprint. The reach is very popular for recreational boating and fishing; the Pine Creek Fishing Access Site is located just below the Pine Creek Bridge on the left bank.

This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,530 cfs to 1,480 cfs with human development, a reduction of 3.3 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC10 include:
•Extensive dike construction Floodplain dikes constructed to protect spring creek fisheries have narrowed the active meander corridor
•Exurban encroachment into the Channel Migration Zone (CMZ) has occurred on terrace surfaces
•Gravel pit and recreational pond development in a meander core may contribute to avulsion risk in the reach.
•Rapid dike construction and armoring following major flooding (1996/1997).
•Increase in primary channel length (sinuosity) with loss of side channels.
•Isolation of 38 percent of the CMZ, mostly avulsion hazard areas that support spring creeks.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC10 include:
•Selective side channel restoration at RM 511.5 (may be difficult to reactivate side channels without affecting developed spring creek fishery
•CMZ Management due to current restriction of 38 percent of the Channel Migration Zone

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6192500	6191500
Location	Livingston	Corwin Springs
Period of Record	1929-2015	1890-2012
Distance To (miles)	4.4	42.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,820	19,500	24,600	27,800	34,200	36,800	42,800	1,530	1,760
Regulated	9,760	19,400	24,500	27,700	34,100	36,800	42,800	1,480	1,680
% Change	-0.61%	-0.51%	-0.41%	-0.36%	-0.29%	0.00%	0.00%	-3.27%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/23/2009	Color	1-meter pixels	6192500	6770
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

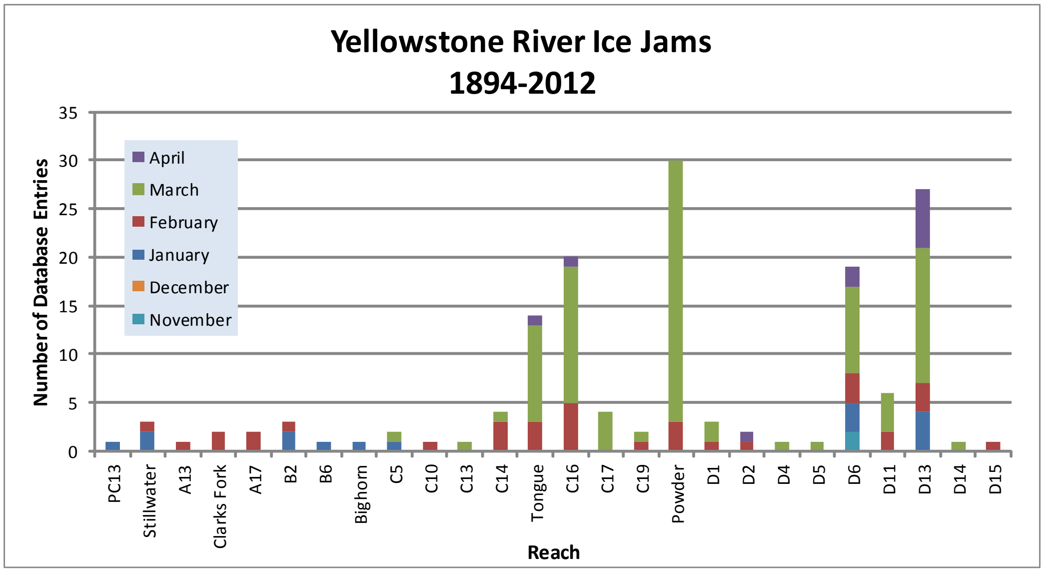
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	2,667	7.3%	3,754	10.3%	1,086
	Flow Deflectors	768	2.1%	674	1.8%	-94
	Between Flow Deflectors	478	1.3%	522	1.4%	44
	Feature Type Totals	**3,914**	**10.7%**	**4,950**	**13.5%**	**1,037**
Floodplain Control						
	Floodplain Dike/Levee	12,431	34.0%	12,431	34.0%	0
	Feature Type Totals	**12,431**	**34.0%**	**12,431**	**34.0%**	**0**
	Reach Totals	**16,344**	**44.7%**	**17,381**	**47.5%**	**1,037**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	16,592	7,240	1.44	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	18,301	1,489	1.08	1950 to 2001:	-24.71%
Change 1950 - 2001	**1,710**	**-5,751**	**-0.35**		

Length of Side Channels Blocked

Pre-1950s (ft)	7,000
Post-1950s (ft)	1,454

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
235	469	465	94	20%	201	159	79%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Flow Deflectors			
	Non-Irrigated	6	0.9%
Dike/Levee			
	Non-Irrigated	247	37.0%
	Totals	**253**	**37.9%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
0.0	27.5	0.0	19.9	0.3

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	31	49	62	55	2.0%	3.2%	4.1%	3.6%
	Totals	**31**	**49**	**62**	**55**	**2.0%**	**3.2%**	**4.1%**	**3.6%**
Agricultural Land									
	Non-Irrigated	817	864	895	852	53.6%	56.7%	58.7%	55.9%
	Irrigated	512	425	190	209	33.6%	27.9%	12.5%	13.7%
	Totals	**1,330**	**1,289**	**1,085**	**1,061**	**87.2%**	**84.5%**	**71.2%**	**69.6%**
Channel									
	Channel	163	186	214	229	10.7%	12.2%	14.0%	15.0%
	Totals	**163**	**186**	**214**	**229**	**10.7%**	**12.2%**	**14.0%**	**15.0%**
ExUrban									
	ExUrban Other	0	0	2	2	0.0%	0.0%	0.1%	0.1%
	ExUrban Undeveloped	0	0	72	0	0.0%	0.0%	4.7%	0.0%
	ExUrban Industrial	0	0	11	11	0.0%	0.0%	0.7%	0.7%
	ExUrban Commercial	0	0	16	16	0.0%	0.0%	1.0%	1.0%
	ExUrban Residential	0	0	62	150	0.0%	0.0%	4.1%	9.9%
	Totals	**0**	**0**	**163**	**179**	**0.0%**	**0.0%**	**10.7%**	**11.7%**
Transportation									
	Public Road	1	1	1	1	0.1%	0.1%	0.1%	0.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**1**	**1**	**1**	**1**	**0.1%**	**0.1%**	**0.1%**	**0.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	56	136	0.0%	0.0%	5.1%	12.8%	0.0%	5.1%	7.7%	12.8%
	Pivot	0	100	37	56	0.0%	7.8%	3.4%	5.3%	7.8%	-4.4%	1.9%	5.3%
	Flood	512	325	97	17	38.5%	25.2%	9.0%	1.6%	-13.3%	-16.2%	-7.4%	-36.9%
	Totals	**512**	**425**	**190**	**209**	**38.5%**	**33.0%**	**17.5%**	**19.7%**	**-5.6%**	**-15.5%**	**2.2%**	**-18.8%**

Non-Irrigated

Multi-Use	706	767	613	521	53.1%	59.5%	56.5%	49.1%	6.4%	-3.0%	-7.4%	-4.0%
Hay/Pasture	112	97	282	331	8.4%	7.5%	26.0%	31.2%	-0.9%	18.5%	5.2%	22.8%
Totals	**817**	**864**	**895**	**852**	**61.5%**	**67.0%**	**82.5%**	**80.3%**	**5.6%**	**15.5%**	**-2.2%**	**18.8%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	22.5	165.1	49.1	0.0	**236.7**
Acres/Valley Mile	9.7	71.2	21.1	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.14	0.25%	1.46	0.02	0.01	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County	Park	**Upstream River Mile**	511
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	508.7
General Location	To near Suce Cr, Wineglass Mtn to west	**Length**	2.30 mi (3.70 km)

General Comments

Narrative Summary

Reach PC11 is located in the Paradise Valley downstream of Deep Creek, and consists of a Partially Confined Anabranching (PCA) reach type, reflected by multiple channels separated by wooded islands, and local abutment of the channel against low glacial terraces. Long floodplain dikes and bank armor installations have isolated natural migration and avulsion areas from the active channel corridor. These dikes and levees narrow the corridor significantly in the downstream direction; whereas in the upper portions of Reach PC11 the active corridor is approximately 2,000 feet wide, it is narrowed approximately 400 feet by floodplain dikes and bank armor at the downstream boundary of Reach PC11.

Some of the most significant impacts to Reach PC11 occurred prior to 1950. This includes the isolation of a major anabranching channel on the east side of the river that has been improved as a spring creek. The dike blocking this channel is located at its upper end in Reach PC10; within Reach PC11this channel is over a mile long.

Although many of the impacts to Reach PC11 occurred prior to 1950, one dike isolated a channel more recently. This 1/4 mile long channel to the west of the main river was blocked off between 1988 and 1991. Within Reach PC11, several channels that have historically been relatively connected to the active river are now largely isolated, forming spring creeks on each side of the river that run parallel to the river for miles. Continual improvements on these spring creeks are evident on the air photos, including original development efforts that included deepening and widening the relic Yellowstone River channels, and re-routing these channels to lengthen them as they parallel the main thread. On the west side of the river, a lengthened spring creek is separated from the river by over a mile of floodplain dike in Reach PC11 alone.

Approximately 35 percent of the bankline in Reach PC11 is armored by Rock Riprap (8,645 feet), and another 8 percent of the bank is protected by flow deflectors (2,047 feet). Approximately 6,900 feet of floodplain dikes protect the spring creek on the west side of the corridor from Yellowstone River overflows. Armor, dikes, and levees have isolated 26 percent of the natural Channel Migration Zone.

Since 1950 the main channel has increased length by approximately 10 percent or 1,200 feet. This trend is common in reaches where side channels have been lost and the main thread has more consolidated flow. The bankfull footprint has grown by 40 acres since 1950, which may reflect main channel expansion due to side channel loss.

Similar to other reaches in Park County, the extent of flood irrigation has dropped in the reach since 1950, and the amount of sprinkler and pivot irrigation has increased. The dominant land use remains agriculture, however, with 139 acres in flood irrigation, 102 acres in sprinkler, and 80 acres in pivot. Another 600 acres are in non-irrigated agriculture. There are almost 80 acres of emergent wetlands in Reach PC10, reflecting a large wet meadow complex across the river from the mouth of Deep Creek.

This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events now considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,550 cfs to 1,500 cfs with human development, a reduction of 3.2 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC11 include:
•Channel Migration Zone restrictions by floodplain dikes and bank armor causing simplification.
•Loss of side channel connectivity due to floodplain dikes and bank armor causing simplification.
•Increase in primary channel length with reduction in side channel length.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC11 include:
•Selective side channel restoration at RM 510L (may be difficult to reactivate side channels without affecting developed spring creek fishery
•CMZ Management due to current restriction of 26 percent of the Channel Migration Zone

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6192500	1619500
Location	Livingston	
Period of Record	1929-2015	
Distance To (miles)	2.1	

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,820	19,500	24,600	27,800	34,200	36,800	42,800	1,550	1,760
Regulated	9,760	19,400	24,500	27,700	34,100	36,800	42,800	1,500	1,680
% Change	-0.61%	-0.51%	-0.41%	-0.36%	-0.29%	0.00%	0.00%	-3.23%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/23/2009	Color	1-meter pixels	6192500	6770
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

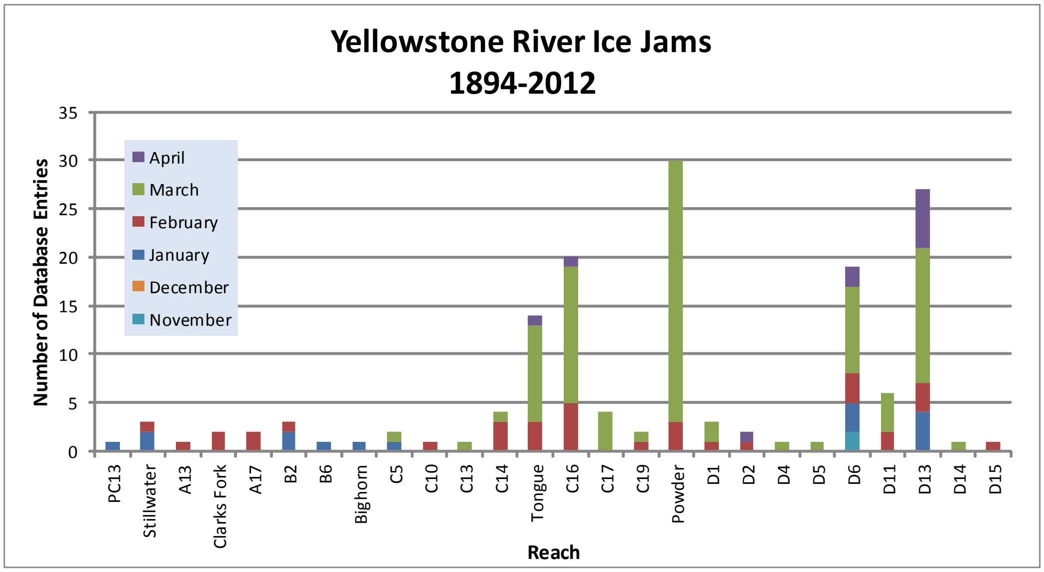
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	8,601	34.6%	8,645	34.8%	45
	Flow Deflectors	1,167	4.7%	1,149	4.6%	-17
	Between Flow Deflectors	1,118	4.5%	897	3.6%	-220
	Feature Type Totals	**10,885**	**43.8%**	**10,692**	**43.0%**	**-193**
Floodplain Control						
	Floodplain Dike/Levee	6,891	27.7%	6,879	27.7%	-12
	Feature Type Totals	**6,891**	**27.7%**	**6,879**	**27.7%**	**-12**
	Reach Totals	**17,775**	**71.5%**	**17,571**	**70.7%**	**-205**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	11,289	12,686	2.12	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	12,432	7,832	1.63	1950 to 2001:	-23.25%
Change 1950 - 2001	**1,144**	**-4,854**	**-0.49**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	1,990

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
211	422	475	104	22%	130	47	36%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Non-Irrigated	106	17.6%
RipRap			
	Irrigated	21	3.4%
Flow Deflectors			
	Irrigated	23	3.9%
Dike/Levee			
	Non-Irrigated	4	0.7%
	Totals	**155**	**25.6%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
34.8	8.8	1.5	0.4	0.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	19	76	75	64	1.5%	6.1%	6.0%	5.2%
	Totals	**19**	**76**	**75**	**64**	**1.5%**	**6.1%**	**6.0%**	**5.2%**
Agricultural Land									
	Non-Irrigated	556	472	472	613	44.6%	37.9%	37.8%	49.2%
	Irrigated	501	447	392	320	40.2%	35.9%	31.4%	25.7%
	Totals	**1,057**	**919**	**863**	**934**	**84.8%**	**73.8%**	**69.3%**	**74.9%**
Channel									
	Channel	164	237	292	232	13.2%	19.0%	23.4%	18.6%
	Totals	**164**	**237**	**292**	**232**	**13.2%**	**19.0%**	**23.4%**	**18.6%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	2	2	0.0%	0.0%	0.2%	0.2%
	Totals	**0**	**0**	**2**	**2**	**0.0%**	**0.0%**	**0.2%**	**0.2%**
Transportation									
	Public Road	6	14	14	14	0.5%	1.1%	1.1%	1.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**6**	**14**	**14**	**14**	**0.5%**	**1.1%**	**1.1%**	**1.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	89	102	0.0%	0.0%	10.3%	10.9%	0.0%	10.3%	0.6%	10.9%
	Pivot	0	0	25	80	0.0%	0.0%	2.9%	8.5%	0.0%	2.9%	5.6%	8.5%
	Flood	501	447	278	138	47.4%	48.6%	32.2%	14.8%	1.2%	-16.4%	-17.4%	-32.6%
	Totals	**501**	**447**	**392**	**320**	**47.4%**	**48.6%**	**45.4%**	**34.3%**	**1.2%**	**-3.2%**	**-11.1%**	**-13.1%**

Non-Irrigated												
Multi-Use	397	396	420	569	37.6%	43.1%	48.7%	60.9%	5.5%	5.6%	12.2%	23.3%
Hay/Pasture	159	76	51	45	15.0%	8.3%	5.9%	4.8%	-6.7%	-2.4%	-1.1%	-10.2%
Totals	**556**	**472**	**472**	**613**	**52.6%**	**51.4%**	**54.6%**	**65.7%**	**-1.2%**	**3.2%**	**11.1%**	**13.1%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	27.5	75.5	55.0	0.0	**158.0**
Acres/Valley Mile	13.5	37.1	27.0	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.26	0.06%	0.13	0.06	0.05	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County	Park	**Upstream River Mile**	508.7
Classification	PCM: Partially confined meandering	**Downstream River Mile**	506.7
General Location	To Carters Bridge	**Length**	2.00 mi (3.22 km)

General Comments

Narrative Summary

Reach PC12 is located in the northernmost portion of the Paradise Valley, consisting of the two miles of river channel upstream of Carters Bridge. The reach is somewhat confined between terraces, Highway 89, and bedrock hillslopes. Carter's Bridge hosts a fishing access site and boat ramp.

Over its two mile length, the banks of Reach PC12 are armored by 7,267 feet of rock riprap and 4,106 feet of flow deflectors. Over 50 percent of the banks are armored. There are also about 8,700 feet of floodplain levees in Reach PC12. About 2,600 feet of this levee extent is the Highway 89 embankment which also forms the bankline as the river approaches the Livingston Ditch Diversion structure. A total of 39 percent of the Channel Migration Zone in this reach has been restricted by physical features such as bank armor and levees.

In 1950, there were 343 acres of land under flood irrigation in the reach. By 2000, that had dropped to about 90 acres, and sprinklers and pivots had expanded to 201 and 16 acres, respectfully. There was also about 51 acres of exurban development in the reach, all of which is just above Carter's Bridge on the west side of the river.

Over 100 acres of wetlands have been mapped in Reach PC12. These wetlands are located in isolated relic channels in the southwest floodplain, and in perched historic meander features in the northeast.

Reach PC12 is located right next to the Livingston gage which is at Carters Bridge. This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,550 cfs to 1,500 cfs with human development, a reduction of 3.2 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC12 include:
•Narrowing of the CMZ to less than half of its natural width, mainly due to long levees that run parallel to the river to protect spring creeks.
•Loss of side channel connectivity due to floodplain dikes and bank armor causing simplification

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC12 include:
•Side channel restoration at RM 508L
•CMZ Management due to current restriction of 39 percent of the Channel Migration Zone
•Bank Stabilization Recommended Practices due to 55 percent of banks being armored in reach
•Irrigation diversion management at Livingston Ditch Diversion

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	142.3	-2.1

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	10,200	20,300	25,600	28,800	35,400	38,200	44,300	1,550	1,760
Regulated	10,100	20,200	25,500	28,700	35,300	38,100	44,200	1,500	1,680
% Change	-0.98%	-0.49%	-0.39%	-0.35%	-0.28%	-0.26%	-0.23%	-3.23%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/23/2009	Color	1-meter pixels	6192500	6770
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

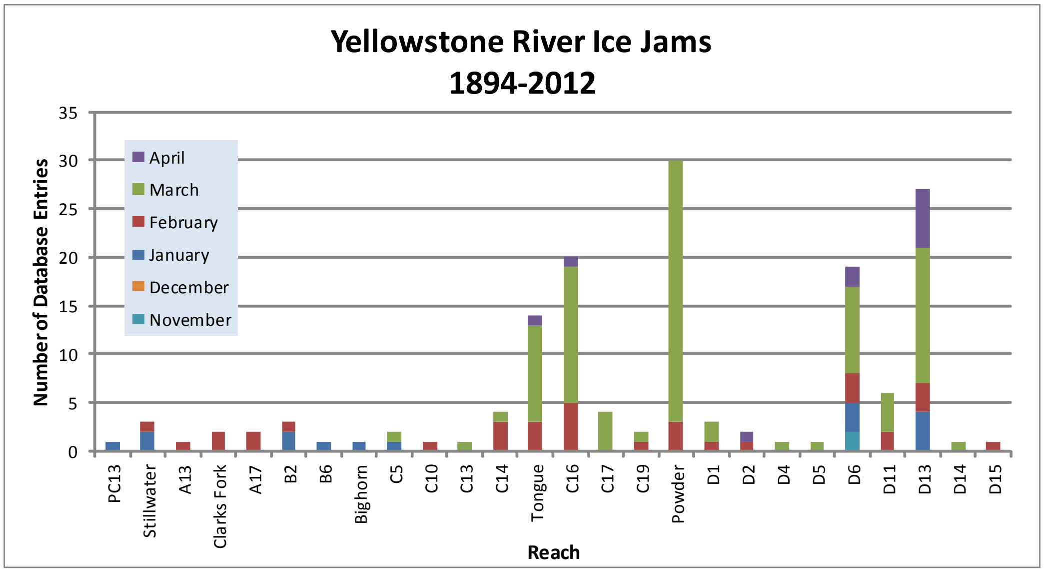
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	7,158	34.6%	7,267	35.1%	109
	Flow Deflectors	1,721	8.3%	1,772	8.6%	51
	Between Flow Deflectors	2,458	11.9%	2,334	11.3%	-124
	Feature Type Totals	**11,337**	**54.8%**	**11,373**	**55.0%**	**36**
Floodplain Control						
	Floodplain Dike/Levee	8,706	42.1%	8,706	42.1%	0
	Feature Type Totals	**8,706**	**42.1%**	**8,706**	**42.1%**	**0**
	Reach Totals	**20,043**	**96.9%**	**20,079**	**97.1%**	**36**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	10,805	8,196	1.76	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	10,337	8,164	1.79	1950 to 2001:	1.78%
Change 1950 - 2001	**-468**	**-31**	**0.03**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
125	249	274	84	31%	126	72	57%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Exurban Other	6	1.6%
RipRap/Flow Deflectors			
	Public Road	10	2.5%
	Non-Irrigated	100	25.1%
	Irrigated	11	2.7%
Flow Deflectors			
	Public Road	1	0.4%
	Irrigated	24	6.0%
Dike/Levee			
	Public Road	3	0.8%
	Totals	**155**	**39.0%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
72.8	10.8	0.0	17.9	3.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	2	2	0.0%	0.0%	0.2%	0.2%
	Other Infrastructure	39	41	51	55	3.7%	3.9%	4.9%	5.2%
	Totals	**39**	**41**	**54**	**57**	**3.7%**	**3.9%**	**5.1%**	**5.4%**
Agricultural Land									
	Non-Irrigated	482	461	471	442	46.0%	44.0%	44.9%	42.2%
	Irrigated	343	334	285	307	32.7%	31.8%	27.1%	29.3%
	Totals	**825**	**795**	**755**	**749**	**78.7%**	**75.8%**	**72.0%**	**71.5%**
Channel									
	Channel	165	163	170	172	15.7%	15.5%	16.2%	16.4%
	Totals	**165**	**163**	**170**	**172**	**15.7%**	**15.5%**	**16.2%**	**16.4%**
ExUrban									
	ExUrban Other	0	0	3	3	0.0%	0.0%	0.3%	0.3%
	ExUrban Undeveloped	0	3	3	3	0.0%	0.3%	0.3%	0.3%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	28	44	45	0.0%	2.6%	4.2%	4.3%
	Totals	**0**	**31**	**51**	**51**	**0.0%**	**2.9%**	**4.8%**	**4.8%**
Transportation									
	Public Road	19	19	19	19	1.8%	1.8%	1.8%	1.8%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**19**	**19**	**19**	**19**	**1.8%**	**1.8%**	**1.8%**	**1.8%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Flood	343	334	172	89	41.6%	42.0%	22.8%	11.9%	0.4%	-19.2%	-10.9%	-29.7%
	Sprinkler	0	0	112	201	0.0%	0.0%	14.9%	26.9%	0.0%	14.9%	12.0%	26.9%
	Pivot	0	0	0	16	0.0%	0.0%	0.0%	2.1%	0.0%	0.0%	2.1%	2.1%
	Totals	**343**	**334**	**285**	**307**	**41.6%**	**42.0%**	**37.7%**	**40.9%**	**0.4%**	**-4.3%**	**3.3%**	**-0.6%**

Non-Irrigated												
Multi-Use	417	416	443	438	50.6%	52.3%	58.7%	58.5%	1.8%	6.3%	-0.1%	8.0%
Hay/Pasture	65	45	28	4	7.9%	5.7%	3.7%	0.5%	-2.2%	-2.0%	-3.1%	-7.3%
Totals	**482**	**461**	**471**	**442**	**58.4%**	**58.0%**	**62.3%**	**59.1%**	**-0.4%**	**4.3%**	**-3.3%**	**0.6%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	19.8	67.5	28.5	0.0	**115.8**
Acres/Valley Mile	10.8	36.8	15.6	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.19	0.08%	0.16	0.09	0.02	0.01

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County	Park	**Upstream River Mile**	506.7
Classification	PCB: Partially confined braided	**Downstream River Mile**	505
General Location	Through canyon upstream of Livingston	**Length**	1.70 mi (2.74 km)

General Comments

Narrative Summary

Reach PC13 flows through Allenspur Canyon, which is a notch carved through a limestone and sandstone ridge that runs perpendicular to the river. Within this notch, the river bottom is 1,000 to 1,800 feet wide, so that the river is not entirely confined. The reach is largely single thread with large point bars, and has several bank migration sites that have exceeded 200 feet of movement since 1950.

There are about 2,000 feet of bank armor in the reach, which covers about 13 percent of the total bankline. There is also about ½ mile of diking that is concentrated just downstream of Carters Bridge on the west floodplain.

Approaching Livingston, the primary modern land use is exurban, although historically the land was primarily used for agriculture. There are over 80 acres of exurban development in Reach PC13, most of which is on the west floodplain. Only 4 acres of land in the reach are irrigated. There is a ~13 acre fishing access site named Free River on an historic island that offers no boating facilities.

Reach PC13 experienced an ice jam-related flood in January of 2007 which flooded one house in the area.

Reach PC13 has seen a dramatic change in channel form since 1950, as it has shifted from a multi-thread anabranching reach type to a single channel with distinct meanders and open bars. In 1950, this reach had 6,600 feet of anabranching channels that flowed around wooded islands. Since then, the river has consolidated into a single thread and lost virtually all of its side channels. Those side channels were not blocked, but they were abandoned with flow consolidation into a single thread. The size of the channel (bankfull area) has increased by about 20 percent. One large meander in the reach is in the process of cutting off, as a prominent chute channel has formed against the east valley wall.

Numerous structures and a portion of the Highway 89 embankment are located within the CMZ in Reach PC13. A total of 8 percent of the CMZ has been restricted by physical features.

In the early 1960's, a dam was proposed for Allenspur Canyon but was ultimately defeated largely due to local resistance. Allen Spur Dam was proposed as a 380-foot tall dam with a 250,000 watt power plant that would have inundated the Paradise Valley up to 30 miles upstream.

This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,550 cfs to 1,500 cfs with human development, a reduction of 3.2 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC13 include:
•Transformation from a multi-thread, anabranching reach type to a single thread channel with open bars.
•Abandonment of over a mile of side channels since 1950 in a 1.7 mile long reach.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC13 include:
•CMZ Management due to development pressure in confined reach

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	140.6	-0.1

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	10,200	20,300	25,600	28,800	35,400	38,200	44,300	1,550	1,760
Regulated	10,100	20,200	25,500	28,700	35,300	38,100	44,200	1,500	1,680
% Change	-0.98%	-0.49%	-0.39%	-0.35%	-0.28%	-0.26%	-0.23%	-3.23%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/26/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

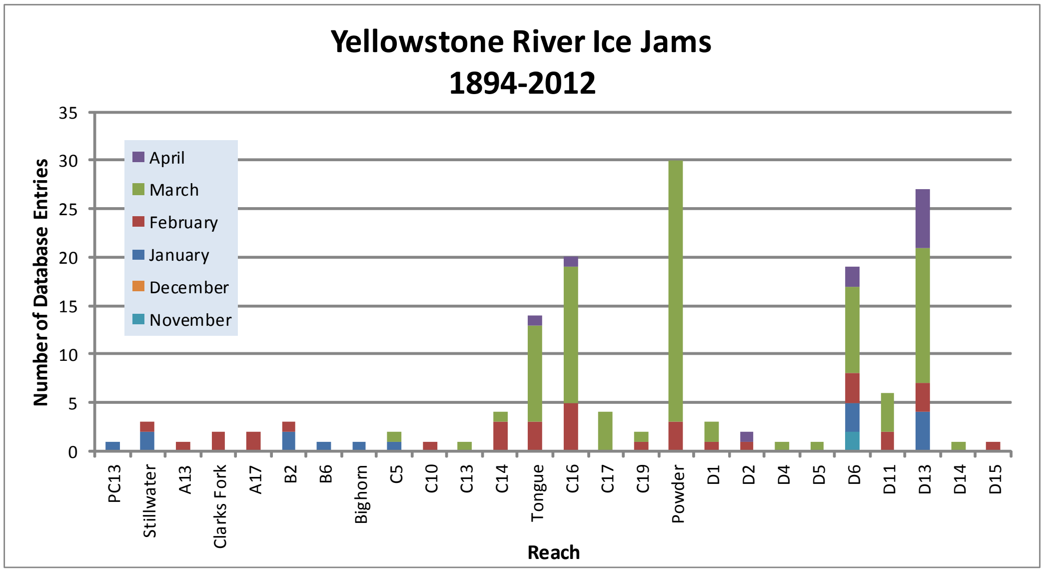
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	1,087	6.6%	1,240	7.6%	153
	Flow Deflectors	456	2.8%	394	2.4%	-62
	Between Flow Deflectors	620	3.8%	481	2.9%	-139
	Feature Type Totals	**2,164**	**13.2%**	**2,115**	**12.9%**	**-49**
Floodplain Control						
	Floodplain Dike/Levee	2,541	15.5%	2,541	15.5%	0
	Feature Type Totals	**2,541**	**15.5%**	**2,541**	**15.5%**	**0**
	Reach Totals	**4,705**	**28.7%**	**4,656**	**28.4%**	**-49**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
1/17/2007	Released		1 house flooded

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	7,508	6,652	1.89	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	8,189		1.00	1950 to 2001:	-46.98%
Change 1950 - 2001	**682**		**-0.89**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
123	246	221	13	6%	15	6	41%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Exurban Other	10	4.4%
RipRap/Flow Deflectors			
	Exurban Residential	6	2.6%
Flow Deflectors			
	Non-Irrigated	3	1.3%
	Totals	**19**	**8.2%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ExUrban	Trans-portation

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	2	3	4	4	0.3%	0.6%	0.8%	0.8%
	Totals	**2**	**3**	**4**	**4**	**0.3%**	**0.6%**	**0.8%**	**0.8%**
Agricultural Land									
	Non-Irrigated	256	225	205	208	54.8%	48.3%	44.0%	44.6%
	Irrigated	36	0	11	4	7.7%	0.0%	2.4%	0.9%
	Totals	**292**	**225**	**217**	**212**	**62.5%**	**48.3%**	**46.4%**	**45.5%**
Channel									
	Channel	156	153	153	157	33.5%	32.9%	32.7%	33.6%
	Totals	**156**	**153**	**153**	**157**	**33.5%**	**32.9%**	**32.7%**	**33.6%**
ExUrban									
	ExUrban Other	2	2	2	2	0.3%	0.3%	0.5%	0.5%
	ExUrban Undeveloped	0	2	2	0	0.0%	0.5%	0.5%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	3	70	78	80	0.7%	15.0%	16.6%	17.1%
	Totals	**5**	**74**	**82**	**82**	**1.1%**	**15.8%**	**17.6%**	**17.6%**
Transportation									
	Public Road	12	12	12	12	2.6%	2.5%	2.5%	2.5%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**12**	**12**	**12**	**12**	**2.6%**	**2.5%**	**2.5%**	**2.5%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	36	0	11	4	12.3%	0.0%	5.2%	2.0%	-12.3%	5.2%	-3.2%	-10.3%
	Totals	**36**	**0**	**11**	**4**	**12.3%**	**0.0%**	**5.2%**	**2.0%**	**-12.3%**	**5.2%**	**-3.2%**	**-10.3%**

Non-Irrigated												
Multi-Use	214	200	192	189	73.2%	88.8%	88.7%	88.9%	15.6%	-0.1%	0.2%	15.7%
Hay/Pasture	42	25	13	19	14.4%	11.2%	6.0%	9.1%	-3.2%	-5.1%	3.0%	-5.3%
Totals	**256**	**225**	**205**	**208**	**87.7%**	**######**	**94.8%**	**98.0%**	**12.3%**	**-5.2%**	**3.2%**	**10.3%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	0.5	8.4	3.3	0.0	**12.2**
Acres/Valley Mile	0.3	6.1	2.4	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.19	0.06%	0.02	0.00	0.03	0.03

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Yellowstone River Reach Narratives — Reach PC14

County	Park	**Upstream River Mile**	505
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	501.7
General Location	Through Interstate bridge crossing to Livingston	**Length**	3.30 mi (5.31 km)

General Comments

Narrative Summary

Reach PC14 is a 3.3 mile long river segment that extends from the mouth of Allenspur Canyon to Sacajawea Park in Livingston. The reach is heavily developed, with almost 600 acres of urban/exurban development in the land use mapping corridor, and another 45 acres developed on 9th Street Island and Siebeck Island. There are over three miles of bank armor in the reach, with about 17,000 feet of rock riprap and 1,600 feet of flow deflectors. This armor covers about 54 percent of the streambanks. Between 2001 and 2011, almost 400 feet of rock riprap located at the head of Siebeck Island was destroyed. There are also over three miles of floodplain dikes mapped in this reach. The physical features protect development on the west floodplain and on Siebeck Island, which is a ~100 acre island just upstream of the Interstate Bridge Physical features have isolated 39 percent of the natural channel migration zone in Reach PC14.

There have been extensive blockages of side channels in Reach PC14. Prior to 1950, about 8,600 feet of side channels were blocked by dikes, and since 1950 dikes have been built to block another mile of side channel.

About 100 acres of wetlands have been mapped in Reach PC14. About 20 of those wetland acres are on Siebeck Island.

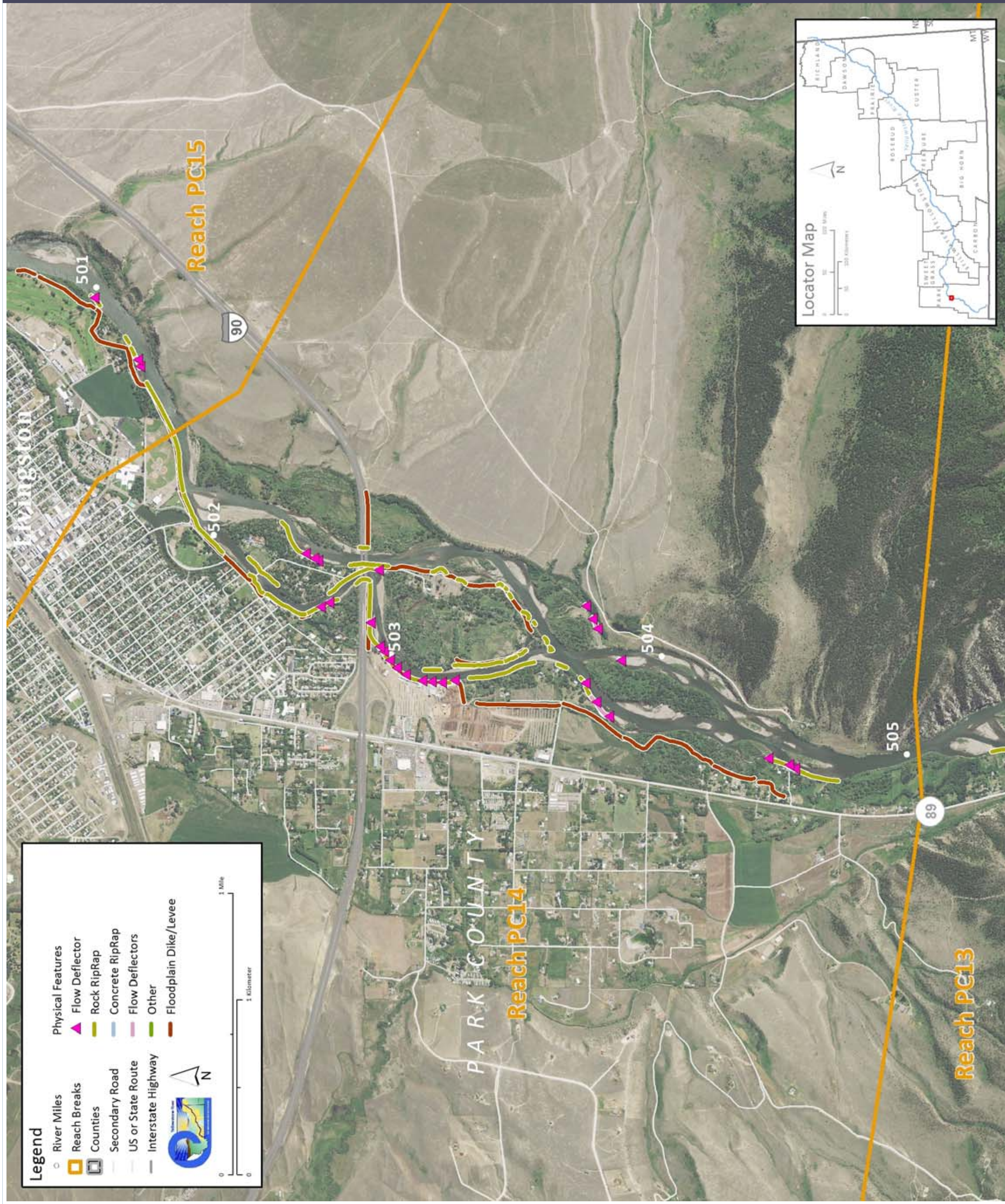
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,570 cfs to 1,510 cfs with human development, a reduction of 3.8 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC14 include:
•Physical features blocking over 13,000 feet of side channels.
•Riprap failure at head of Siebeck Island
•Extensive CMZ Restriction with floodplain development.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC14 include:
•Side channel restoration at RM 504.6L
•Bank armor removal at head of Siebeck Island at RM 503.8
•CMZ management due to 38 percent restriction of Channel Migration Zone
•Russian olive removal
•Bank Stabilization Recommended Practices due to extensive armoring in reach (51 percent of bankline)

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	137.3	1.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	10,200	20,300	25,600	28,800	35,400	38,200	44,300	1,570	1,760
Regulated	10,100	20,200	25,500	28,700	35,300	38,100	44,200	1,510	1,680
% Change	-0.98%	-0.49%	-0.39%	-0.35%	-0.28%	-0.26%	-0.23%	-3.82%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

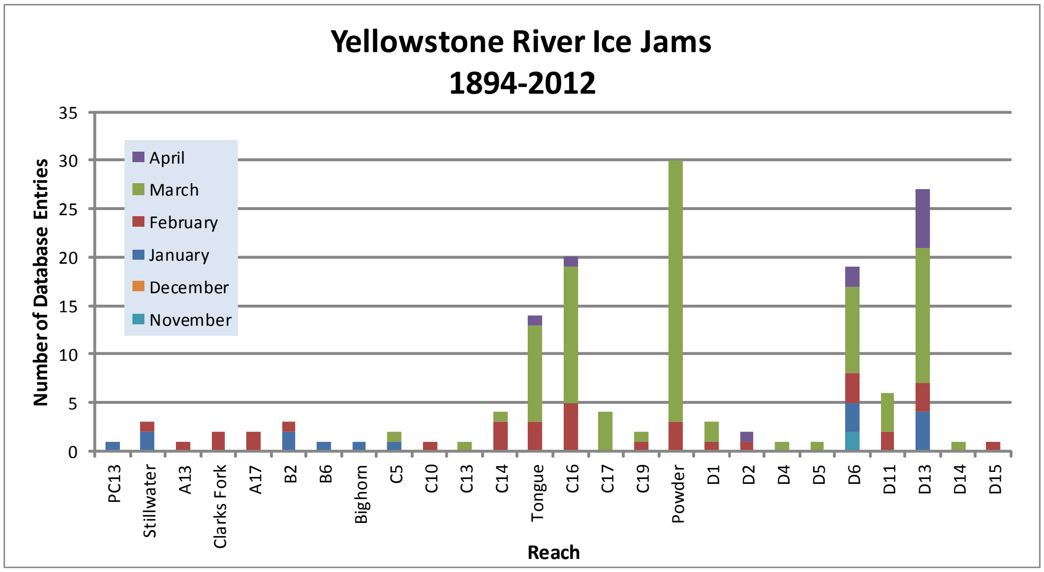
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	17,321	47.4%	16,932	46.4%	-390
	Gabions	0	0.0%	149	0.4%	149
	Flow Deflectors	961	2.6%	961	2.6%	0
	Between Flow Deflectors	629	1.7%	621	1.7%	-8
	Feature Type Totals	**18,911**	**51.8%**	**18,662**	**51.1%**	**-249**
Floodplain Control						
	Floodplain Dike/Levee	18,388	50.4%	17,937	49.1%	-451
	Feature Type Totals	**18,388**	**50.4%**	**17,937**	**49.1%**	**-451**
	Reach Totals	**37,299**	**102.2%**	**36,599**	**100.3%**	**-700**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	18,451	26,163	2.42	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	18,253	18,762	2.03	1950 to 2001:	-16.13%
Change 1950 - 2001	**-198**	**-7,401**	**-0.39**		

Length of Side Channels Blocked

Pre-1950s (ft)	8,601
Post-1950s (ft)	5,546

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
171	342	634	225	35%	63	44	69%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Urban Industrial	17	2.4%
	Interstate	5	0.6%
RipRap/Flow Deflectors			
	Urban Residential	6	0.8%
	Urban Industrial	15	2.2%
	Exurban Residential	19	2.8%
RipRap			
	Exurban Residential	15	2.1%
Flow Deflectors			
	Non-Irrigated	1	0.1%
Dike/Levee			
	Urban Other	66	9.5%
	Non-Irrigated	10	1.4%
	Exurban Residential	115	16.4%
	Totals	**268**	**38.5%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
0.0	4.0	0.0	135.2	9.2

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	2	1	1	1	0.1%	0.1%	0.1%	0.1%
	Totals	**2**	**1**	**1**	**1**	**0.1%**	**0.1%**	**0.1%**	**0.1%**
Agricultural Land									
	Non-Irrigated	662	494	415	410	42.3%	31.6%	26.6%	26.3%
	Irrigated	150	26	34	34	9.6%	1.7%	2.2%	2.2%
	Totals	**811**	**520**	**449**	**444**	**51.9%**	**33.3%**	**28.7%**	**28.4%**
Channel									
	Channel	416	432	443	448	26.6%	27.6%	28.4%	28.7%
	Totals	**416**	**432**	**443**	**448**	**26.6%**	**27.6%**	**28.4%**	**28.7%**
ExUrban									
	ExUrban Other	9	0	0	0	0.5%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	15	4	4	0.0%	1.0%	0.2%	0.2%
	ExUrban Industrial	1	94	94	94	0.0%	6.0%	6.0%	6.0%
	ExUrban Commercial	0	19	28	28	0.0%	1.2%	1.8%	1.8%
	ExUrban Residential	28	85	140	140	1.8%	5.5%	9.0%	9.0%
	Totals	**37**	**214**	**266**	**266**	**2.4%**	**13.7%**	**17.1%**	**17.1%**
Transportation									
	Public Road	18	33	41	41	1.2%	2.1%	2.6%	2.6%
	Interstate	0	34	34	34	0.0%	2.2%	2.2%	2.2%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**18**	**67**	**75**	**75**	**1.2%**	**4.3%**	**4.8%**	**4.8%**
Urban									
	Urban Other	49	61	61	61	3.2%	3.9%	3.9%	3.9%
	Urban Residential	183	226	226	226	11.7%	14.5%	14.5%	14.5%
	Urban Commercial	20	42	42	42	1.3%	2.7%	2.7%	2.7%
	Urban Undeveloped	25	0	0	0	1.6%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**277**	**328**	**328**	**328**	**17.7%**	**21.0%**	**21.0%**	**21.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	33	33	0.0%	0.0%	7.3%	7.4%	0.0%	7.3%	0.1%	7.4%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	150	26	1	1	18.4%	5.1%	0.2%	0.2%	-13.4%	-4.9%	0.0%	-18.3%
	Totals	**150**	**26**	**34**	**34**	**18.4%**	**5.1%**	**7.5%**	**7.6%**	**-13.4%**	**2.4%**	**0.1%**	**-10.9%**

Non-Irrigated												
Multi-Use	507	406	415	410	62.5%	78.1%	92.5%	92.4%	15.6%	14.4%	-0.1%	29.9%
Hay/Pasture	154	87	0	0	19.0%	16.8%	0.0%	0.0%	-2.2%	-16.8%	0.0%	-19.0%
Totals	**662**	**494**	**415**	**410**	**81.6%**	**94.9%**	**92.5%**	**92.4%**	**13.4%**	**-2.4%**	**-0.1%**	**10.9%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	15.3	26.4	51.2	0.0	**93.0**
Acres/Valley Mile	5.1	8.8	17.1	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	4.74	0.89%	3.68	1.92	0.45	1.36

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County	Park	**Upstream River Mile**	501.7
Classification	PCS: Partially confined straight	**Downstream River Mile**	499.9
General Location	To Mayors Landing	**Length**	1.80 mi (2.90 km)

General Comments

Narrative Summary

Reach PC15 is a 1.83 mile long river segment that extends from Sacajawea Park to the KPRK Bridge (Hwy 89) in Livingston. Within the reach, the river largely flows along the east valley wall, with extensive development on the west side of the river. There are almost 463 acres of urban development in the land use mapping corridor within this reach. There is also over a mile of bank armor, almost all of which is on the left (west) bank of the river. This includes about 5,000 feet of rock riprap and 600 feet of flow deflectors, which drape about 29 percent of the bankline. There are also 9,000 feet of floodplain dikes mapped in this reach, and again, they are on the west side of the river. The physical features have restricted about one half of the river's natural Channel Migration Zone in Reach PC15.

The Vallis Ditch Diversion diverts water from a side channel on the east side of the river at RM 500.4. Across the river from the diversion, Mayor's Landing is a popular ~3 acre fishing access site with a boat ramp.

About 50 acres of wetlands have been mapped in Reach PC15, and most of these remain connected to the main channel. About 20 of those wetland acres are on Siebeck Island.

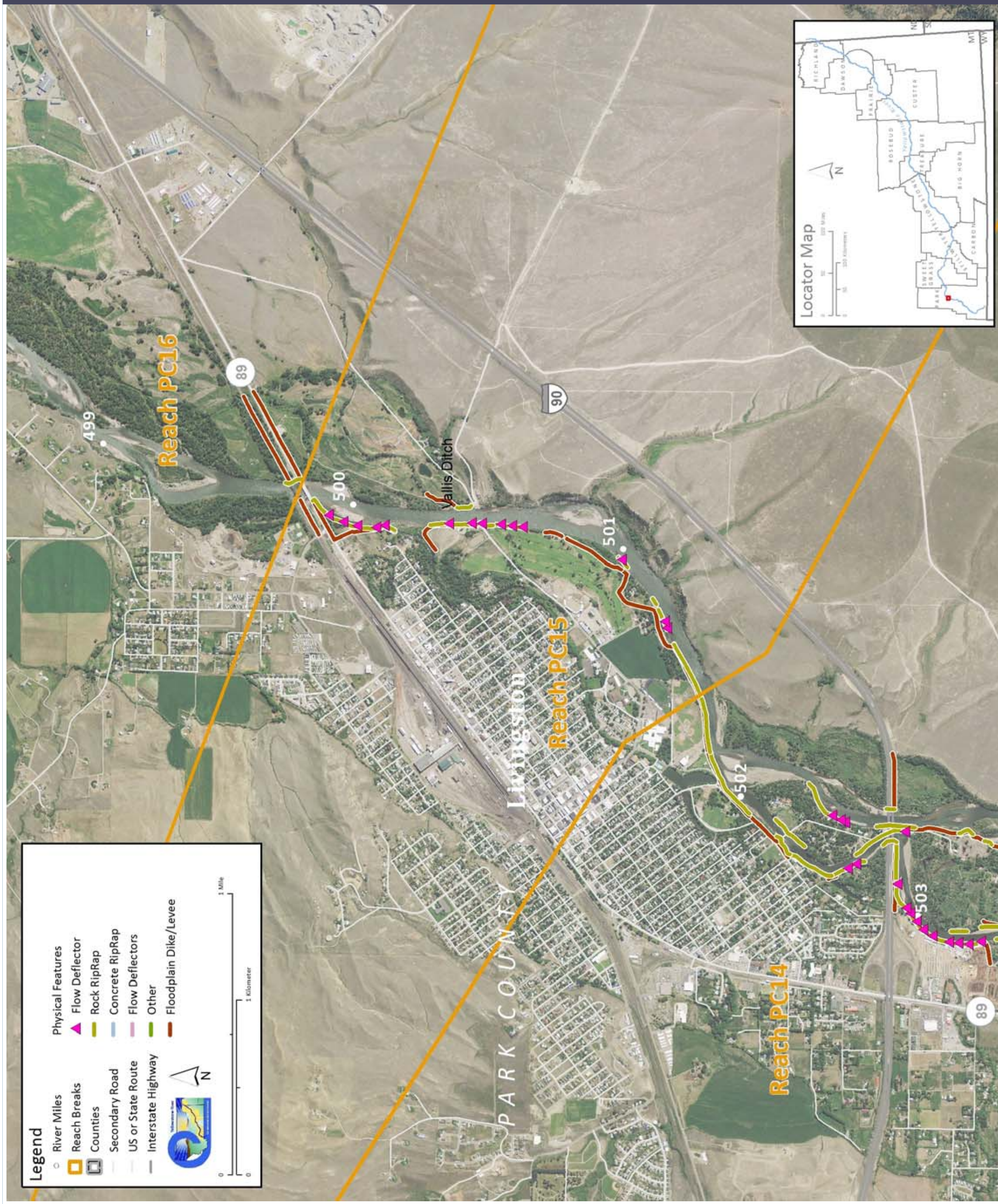
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,570 cfs to 1,510 cfs with human development, a reduction of 3.8 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC15 include:
•Physical features blocking over 13,000 feet of side channels.
•Extensive CMZ Restriction with floodplain development.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC15 include:
•CMZ Management due to current restriction of 53 percent of the Channel Migration Zone
•Channel Bank Stabilization Recommended Practices due to 29 percent of banks being armored in reach
•Irrigation diversion management at Vallis Ditch Diversion

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	135.5	4.9

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	10,200	20,300	25,600	28,800	35,400	38,200	44,300	1,570	1,760
Regulated	10,100	20,200	25,500	28,700	35,300	38,100	44,200	1,510	1,680
% Change	-0.98%	-0.49%	-0.39%	-0.35%	-0.28%	-0.26%	-0.23%	-3.82%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

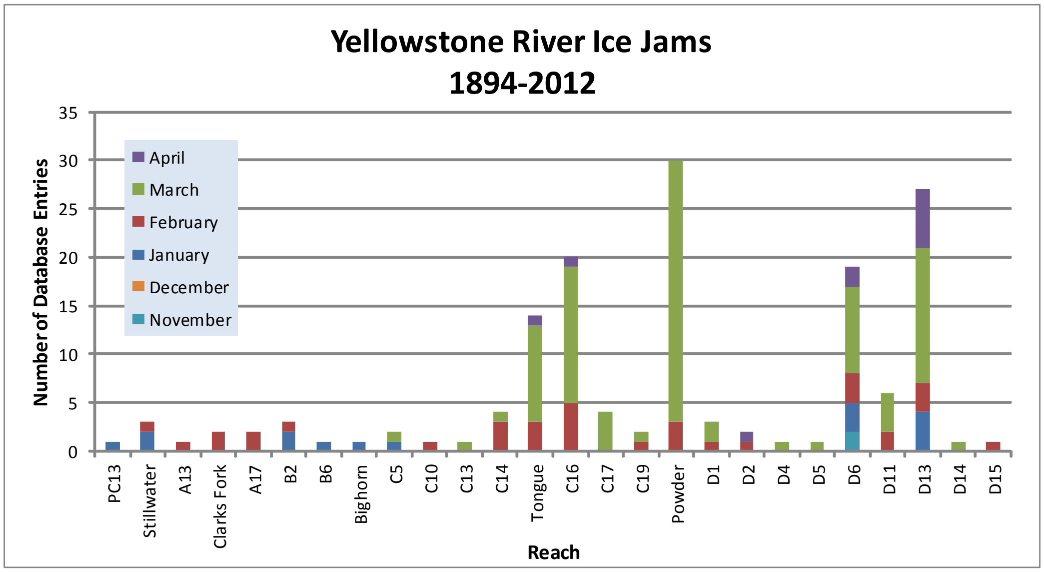
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	4,637	24.5%	4,880	25.8%	243
	Flow Deflectors	613	3.2%	613	3.2%	0
	Between Flow Deflectors	139	0.7%	0	0.0%	-139
	Feature Type Totals	**5,389**	**28.5%**	**5,493**	**29.1%**	**104**
Floodplain Control						
	Floodplain Dike/Levee	9,032	47.8%	9,032	47.8%	0
	Feature Type Totals	**9,032**	**47.8%**	**9,032**	**47.8%**	**0**
	Reach Totals	**14,421**	**76.3%**	**14,525**	**76.8%**	**104**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	9,864	1,031	1.10	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	9,453		1.00	1950 to 2001:	-9.47%
Change 1950 - 2001	**-411**		**-0.10**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
79	158	150	36	24%	284	196	69%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Non-Irrigated	2	0.5%
Dike/Levee			
	Urban Other	230	53.0%
	Totals	**232**	**53.5%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
0.0	18.1	0.0	200.8	5.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	7	13	26	26	0.6%	1.2%	2.4%	2.4%
	Totals	**7**	**13**	**26**	**26**	**0.6%**	**1.2%**	**2.4%**	**2.4%**
Agricultural Land									
	Non-Irrigated	504	413	310	350	48.1%	39.4%	29.5%	33.4%
	Irrigated	14	18	18	18	1.3%	1.7%	1.7%	1.7%
	Totals	**518**	**431**	**328**	**369**	**49.4%**	**41.1%**	**31.3%**	**35.2%**
Channel									
	Channel	91	97	109	106	8.7%	9.3%	10.4%	10.1%
	Totals	**91**	**97**	**109**	**106**	**8.7%**	**9.3%**	**10.4%**	**10.1%**
ExUrban									
	ExUrban Other	5	0	0	0	0.5%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	3	17	51	14	0.3%	1.6%	4.9%	1.3%
	ExUrban Commercial	0	0	0	20	0.0%	0.0%	0.0%	1.9%
	ExUrban Residential	0	4	17	17	0.0%	0.4%	1.6%	1.6%
	Totals	**8**	**21**	**69**	**51**	**0.7%**	**2.0%**	**6.5%**	**4.8%**
Transportation									
	Public Road	18	18	18	18	1.7%	1.7%	1.7%	1.7%
	Interstate	0	3	3	3	0.0%	0.3%	0.3%	0.3%
	Railroad	14	14	13	13	1.3%	1.3%	1.2%	1.2%
	Totals	**31**	**34**	**34**	**34**	**3.0%**	**3.3%**	**3.2%**	**3.2%**
Urban									
	Urban Other	21	86	123	123	2.0%	8.2%	11.7%	11.7%
	Urban Residential	205	236	246	246	19.6%	22.5%	23.5%	23.5%
	Urban Commercial	49	68	68	49	4.7%	6.5%	6.5%	4.7%
	Urban Undeveloped	78	17	0	0	7.4%	1.7%	0.0%	0.0%
	Urban Industrial	41	45	46	46	3.9%	4.3%	4.4%	4.4%
	Totals	**394**	**453**	**483**	**463**	**37.6%**	**43.2%**	**46.1%**	**44.2%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	18	18	0.0%	0.0%	5.5%	4.9%	0.0%	5.5%	-0.6%	4.9%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	14	18	0	0	2.6%	4.2%	0.0%	0.0%	1.6%	-4.2%	0.0%	-2.6%
	Totals	**14**	**18**	**18**	**18**	**2.6%**	**4.2%**	**5.5%**	**4.9%**	**1.6%**	**1.3%**	**-0.6%**	**2.3%**

Non-Irrigated

Multi-Use	327	316	246	282	63.2%	73.3%	75.2%	76.4%	10.2%	1.8%	1.2%	13.2%
Hay/Pasture	177	97	63	69	34.2%	22.4%	19.3%	18.7%	-11.8%	-3.2%	-0.6%	-15.6%
Totals	**504**	**413**	**310**	**350**	**97.4%**	**95.8%**	**94.5%**	**95.1%**	**-1.6%**	**-1.3%**	**0.6%**	**-2.3%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	2.8	36.7	10.9	0.0	**50.5**
Acres/Valley Mile	1.6	20.9	6.2	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.72	0.23%	0.49	0.34	0.07	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Yellowstone River Reach Narratives

Reach PC16

County	Park	**Upstream River Mile**	499.9
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	495.6
General Location	To just upstream of Hwy 89 bridge	**Length**	4.30 mi (6.92 km)

General Comments

Narrative Summary

Reach PC16 is 4.3 miles long, extending from the KPRK Bridge (Hwy 89) in Livingston almost to the Highway 89 Bridge downstream. Within the reach, the river makes a large swing from a northerly trend to an easterly trend. The reach is dynamic, as multiple wooded islands, and intermittently flows along the north valley wall. In 2001, there were about 4.2 miles of side channels in the reach, indicating that there is as almost much side channel as main channel in this segment of the Yellowstone River. In some areas the river corridor is over 2,000 feet wide.

There are over 8,000 feet of bank armor in Reach PC16, about 6,500 feet of which is rock riprap. In 2011, there were 1,700 feet of flow deflectors in the reach, after about 200 feet had been destroyed between 2001 and 2011. These flow deflectors were on a large meander bend; they were flanked, and the river has migrated to the southeast about 200 feet beyond their original location. This erosion also damaged a large diversion structure. Bank armor covers about 18 percent of the total bankline. There are also 8,200 feet of mapped floodplain dikes in the reach. Prior to 1950, a 1,900-foot long channel was blocked at its upper end by the highway and Railroad Bridge approaches at the KPRK Bridge.

Land uses in Reach PC16 are mixed, including urban/exurban, irrigated agriculture, and non-irrigated agriculture. In 1950, over 660 acres were in flood irrigation and by 2011 that number had been reduced to 70 acres, with 173 acres being converted to sprinkler irrigation and 246 to pivot. Exurban development is most dense on the left (north) bank of the river, where the valley wall consists of erosion-resistant sandstone that is out of the Channel Migration Zone.

Over 200 acres of wetlands have been mapped in Reach PC16, most of which are emergent marshes and wet meadows. Most of these wetlands are in non-irrigated hay pastures.

There is one pipeline crossing in this reach. The crossing is near Rustad Lane, and is a natural gas line owned by NW Energy, LLC.

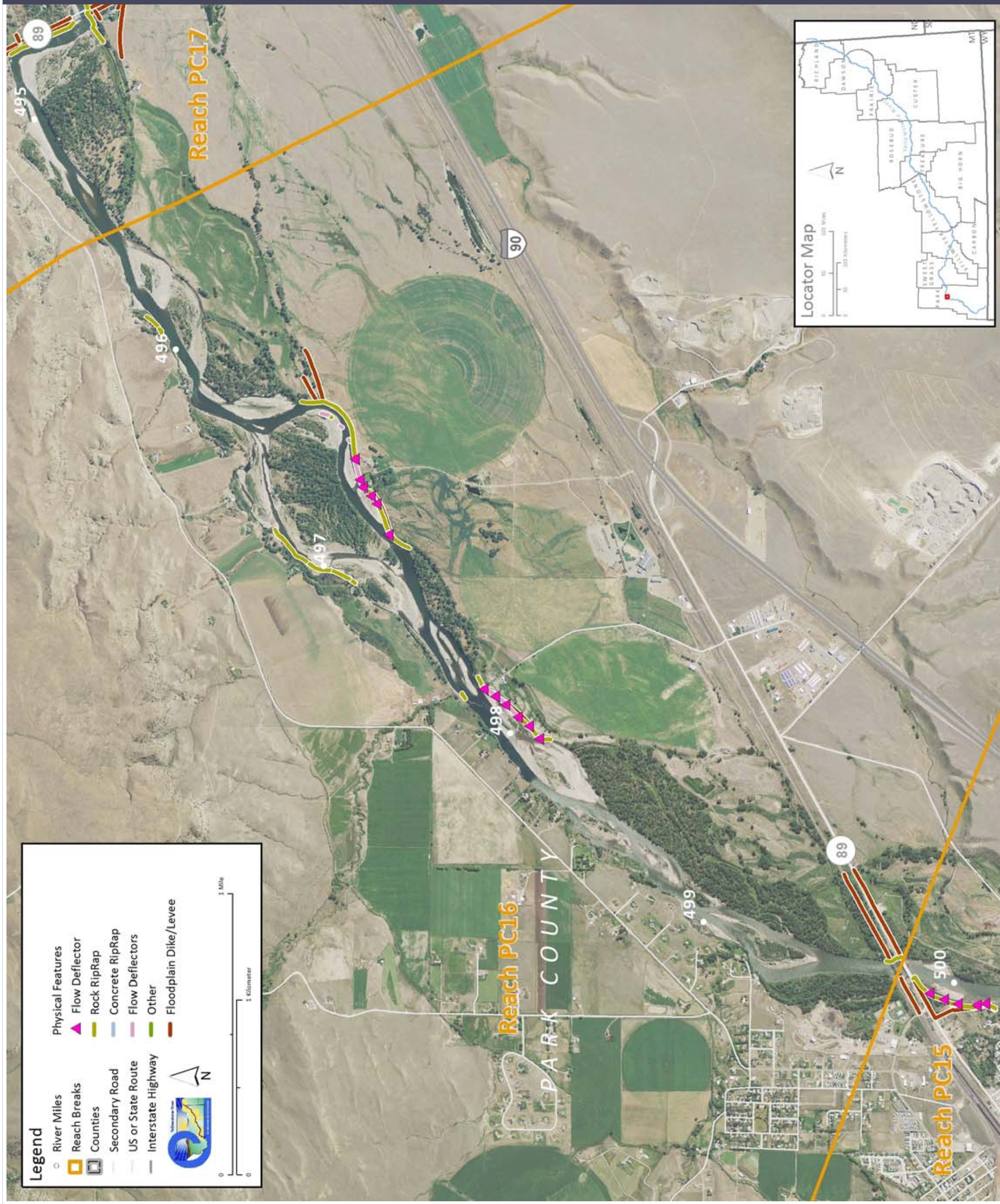
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,580 cfs to 1,510 cfs with human development, a reduction of 4.4 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC16 include:
•Flanking of flow deflectors and sever erosion behind.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC16 include:
•Side channel restoration below transportation embankment at RM 499.4L
•Flanked bank armor removal at RM 496.8
•CMZ Management due to current restriction of 14 percent of the Channel Migration Zone
•Pipeline Practices at natural gas crossing at RM 497.9 (natural gas may have special consideration in Practice)
•Irrigation diversion management at Vallis Ditch Diversion at RM 496.5

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	131.2	6.7

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	10,400	20,600	25,900	29,200	35,900	38,700	44,900	1,580	1,760
Regulated	10,300	20,500	25,800	29,100	35,800	38,600	44,800	1,510	1,680
% Change	-0.96%	-0.49%	-0.39%	-0.34%	-0.28%	-0.26%	-0.22%	-4.43%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

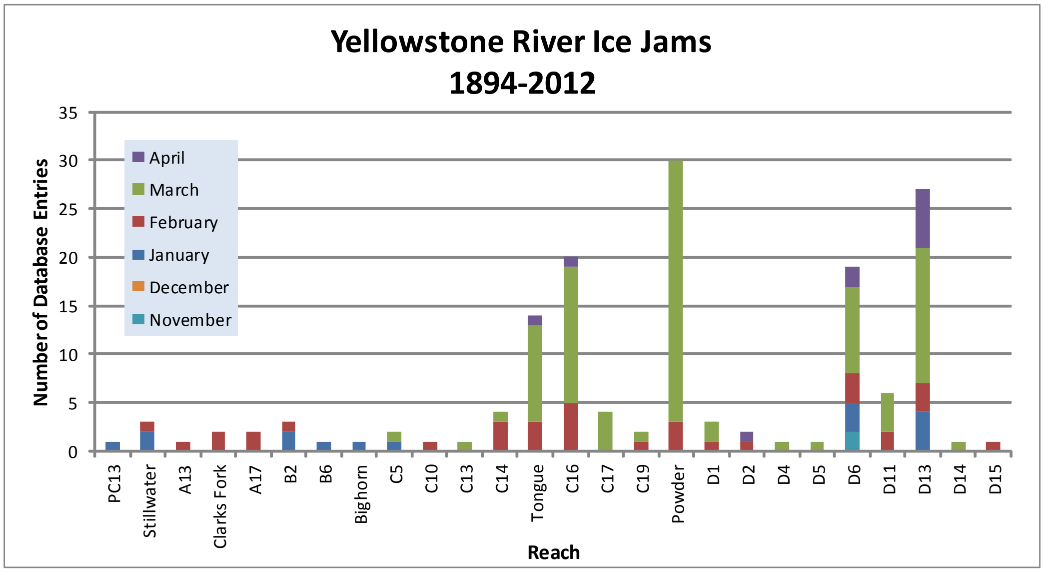
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	4,199	9.2%	6,475	14.2%	2,276
	Flow Deflectors	784	1.7%	759	1.7%	-25
	Between Flow Deflectors	1,126	2.5%	944	2.1%	-182
	Feature Type Totals	**6,109**	**13.4%**	**8,178**	**18.0%**	**2,069**
Floodplain Control						
	Floodplain Dike/Levee	8,196	18.0%	7,453	16.4%	-744
	Feature Type Totals	**8,196**	**18.0%**	**7,453**	**16.4%**	**-744**
	Reach Totals	**14,305**	**31.4%**	**15,631**	**34.3%**	**1,326**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	23,645	25,912	2.10	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	22,759	22,182	1.97	1950 to 2001:	-5.78%
Change 1950 - 2001	**-887**	**-3,729**	**-0.12**		

Length of Side Channels Blocked

Pre-1950s (ft)	1,901
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
212	423	759	52	7%	221	84	38%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	1	0.1%
	Non-Irrigated	89	9.0%
RipRap/Flow Deflectors			
	Non-Irrigated	18	1.9%
	Irrigated	15	1.5%
RipRap			
	Non-Irrigated	6	0.6%
	Irrigated	10	1.0%
	Totals	**140**	**14.3%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
0.1	18.1	8.2	12.6	5.4

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	47	130	182	156	1.9%	5.2%	7.3%	6.3%
	Totals	**47**	**130**	**182**	**156**	**1.9%**	**5.2%**	**7.3%**	**6.3%**
Agricultural Land									
	Non-Irrigated	1,299	956	824	1,042	52.3%	38.5%	33.2%	42.0%
	Irrigated	662	802	708	488	26.7%	32.3%	28.5%	19.7%
	Totals	**1,961**	**1,758**	**1,532**	**1,530**	**79.0%**	**70.8%**	**61.7%**	**61.6%**
Channel									
	Channel	433	388	463	485	17.4%	15.6%	18.6%	19.6%
	Totals	**433**	**388**	**463**	**485**	**17.4%**	**15.6%**	**18.6%**	**19.6%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	17	0	0	0.0%	0.7%	0.0%	0.0%
	ExUrban Industrial	0	31	0	0	0.0%	1.3%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	1	100	203	208	0.0%	4.0%	8.2%	8.4%
	Totals	**1**	**149**	**203**	**208**	**0.0%**	**6.0%**	**8.2%**	**8.4%**
Transportation									
	Public Road	27	28	28	28	1.1%	1.1%	1.1%	1.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	5	5	5	5	0.2%	0.2%	0.2%	0.2%
	Totals	**32**	**33**	**33**	**33**	**1.3%**	**1.3%**	**1.3%**	**1.3%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	8	24	37	37	0.3%	1.0%	1.5%	1.5%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	33	33	0.0%	0.0%	1.3%	1.3%
	Totals	**8**	**24**	**69**	**69**	**0.3%**	**1.0%**	**2.8%**	**2.8%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	151	173	0.0%	0.0%	9.8%	11.3%	0.0%	9.8%	1.5%	11.3%
	Pivot	0	0	244	246	0.0%	0.0%	15.9%	16.1%	0.0%	15.9%	0.1%	16.1%
	Flood	662	802	314	70	33.8%	45.6%	20.5%	4.6%	11.8%	-25.1%	-15.9%	-29.2%
	Totals	**662**	**802**	**708**	**488**	**33.8%**	**45.6%**	**46.2%**	**31.9%**	**11.8%**	**0.6%**	**-14.3%**	**-1.8%**

Non-Irrigated												
Multi-Use	1,119	880	550	593	57.1%	50.0%	35.9%	38.7%	-7.0%	-14.1%	2.8%	-18.3%
Hay/Pasture	180	77	274	449	9.2%	4.4%	17.9%	29.3%	-4.8%	13.5%	11.5%	20.2%
Totals	**1,299**	**956**	**824**	**1,042**	**66.2%**	**54.4%**	**53.8%**	**68.1%**	**-11.8%**	**-0.6%**	**14.3%**	**1.8%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	10.6	154.4	51.5	0.0	**216.5**
Acres/Valley Mile	2.7	39.4	13.1	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.84	0.12%	0.83	0.29	0.12	0.05

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Yellowstone River Reach Narratives — Reach PC17

County	Park	**Upstream River Mile**	495.6
Classification	PCB: Partially confined braided	**Downstream River Mile**	493.6
General Location	Through Hwy 89 bridge crossing to Shields River	**Length**	2.00 mi (3.22 km)

General Comments

Narrative Summary

Reach PC17 is 2.0 miles long, extending from just above the Highway 89 Bridge to just below the mouth of the Shields River. The reach is highly impacted by the two bridges that cross the river in the middle of the reach. One is the Highway 89 Bridge and the other is an abandoned railroad bridge that runs parallel to it just upstream.

There is over a mile of bank armor in Reach PC17, about 5,700 feet of which is rock riprap and another 130 feet is flow deflectors. About 28 percent of the total bankline, including those of side channels, is armored. Most of the armor is associated with the bridges.

About 25 percent of the Channel Migration Zone in Reach PC17 has been restricted by physical features. Much of this restriction takes place near the upper end of the reach, where the Highway 89 Bridge has restricted the natural CMZ from a width of 1800 feet down to 300 feet, isolating about 90 acres of ground downstream of the bridge approach. This constriction at the bridge has also caused extensive deposition upstream, and as a result the river currently flows parallel to the highway before “doglegging” through the bridge opening.

There are also 7,300 feet of mapped floodplain dikes in the reach. These dikes are all associated with the transportation prisms at the bridges. Construction of the bridges also resulted in the blockage of about 3,950 feet of side channel prior to 1950 on the north floodplain just downstream.

Land uses in Reach PC17 are almost entirely agricultural, with historic flood irrigation converting to sprinkler and pivot, and some exurban development. The major land use in the reach, however, is non-irrigated agriculture.

About 85 acres of wetlands have been mapped in Reach PC17, most of which are emergent marshes and wet meadows. Most of these wetlands are in non-irrigated hay pastures or multi-use riparian bottoms.

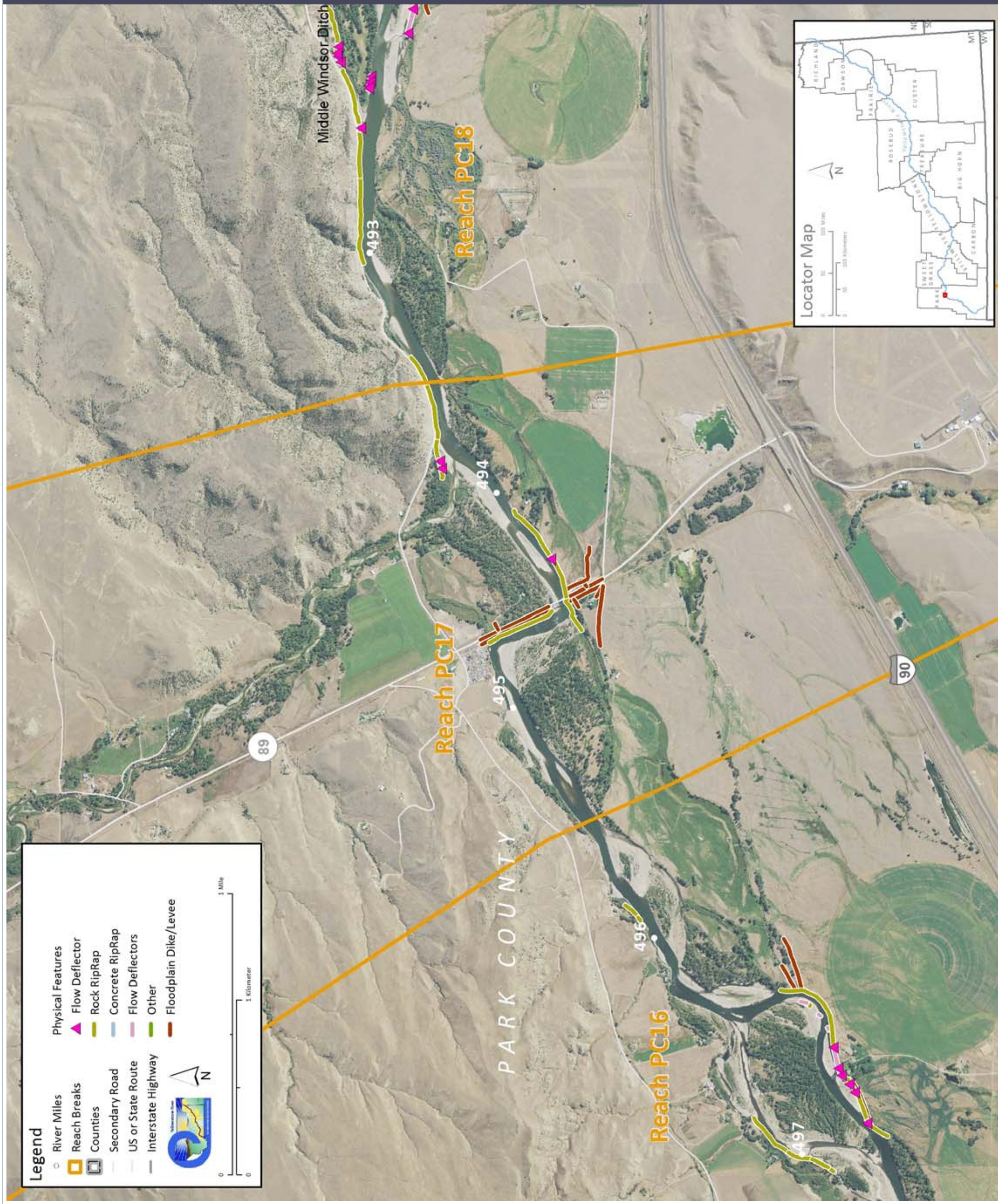
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,720 cfs to 1,560 cfs with human development, a reduction of 9.3 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC17 include:
•Constriction of CMZ at bridge and poor river alignment to structure.
•Side channel blockage by transportation embankment.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC17 include:
•Floodplain restoration/connectivity below transportation embankment at RM 494.5
•Side channel restoration below transportation embankment at RM 494.5
•CMZ Management due to current restriction of 25 percent of the Channel Migration Zone
•Bank Stabilization Recommended Practices due to the extent of armoring in the reach (28 percent armored banks)

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	129.2	11.0

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	10,400	20,600	25,900	29,200	35,900	38,700	44,900	1,720	1,760
Regulated	10,300	20,500	25,800	29,100	35,800	38,600	44,800	1,560	1,680
% Change	-0.96%	-0.49%	-0.39%	-0.34%	-0.28%	-0.26%	-0.22%	-9.30%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

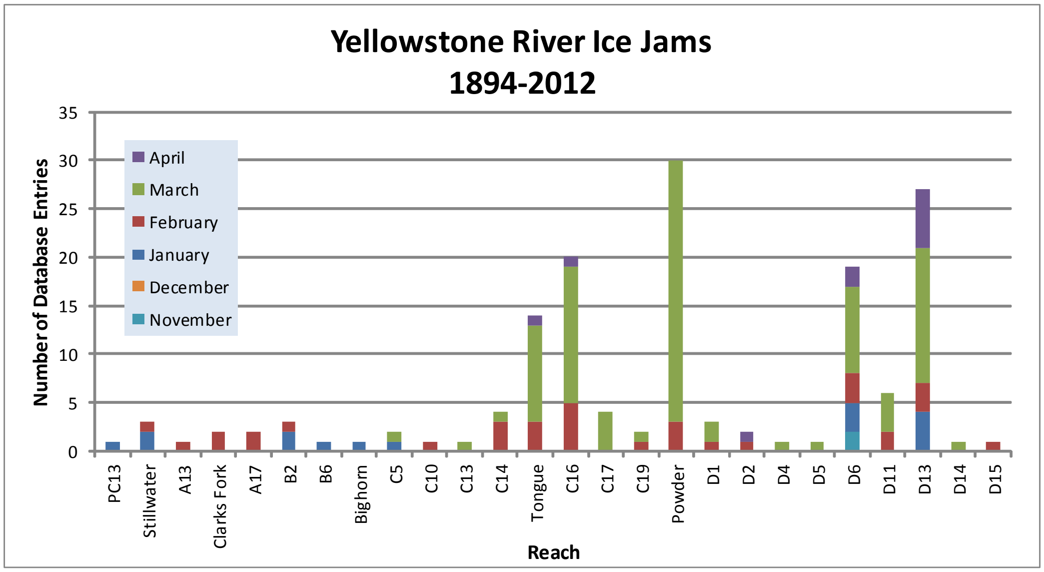
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	5,760	27.6%	5,704	27.3%	-56
	Flow Deflectors	78	0.4%	134	0.6%	56
	Feature Type Totals	**5,838**	**28.0%**	**5,838**	**28.0%**	**0**
Floodplain Control						
	Floodplain Dike/Levee	7,290	34.9%	7,290	34.9%	0
	Feature Type Totals	**7,290**	**34.9%**	**7,290**	**34.9%**	**0**
	Reach Totals	**13,128**	**62.9%**	**13,128**	**62.9%**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	10,030	2,384	1.24	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	10,430	2,345	1.22	1950 to 2001:	-1.04%
Change 1950 - 2001	**400**	**-39**	**-0.01**		

Length of Side Channels Blocked

Pre-1950s (ft)	3,948
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
112	223	209	25	12%	213	81	38%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Non-Irrigated	90	21.2%
RipRap/Flow Deflectors			
	Public Road	2	0.4%
RipRap			
	Railroad	4	1.0%
	Non-Irrigated	10	2.4%
	Totals	**106**	**25.1%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
18.3	0.0	0.0	4.8	2.3

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	11	31	38	44	1.1%	3.2%	3.9%	4.5%
	Totals	**11**	**31**	**38**	**44**	**1.1%**	**3.2%**	**3.9%**	**4.5%**
Agricultural Land									
	Non-Irrigated	462	521	493	611	47.6%	53.6%	50.8%	62.9%
	Irrigated	384	255	255	125	39.5%	26.3%	26.2%	12.9%
	Totals	**846**	**776**	**748**	**736**	**87.1%**	**79.8%**	**77.0%**	**75.8%**
Channel									
	Channel	96	126	131	132	9.9%	13.0%	13.5%	13.6%
	Totals	**96**	**126**	**131**	**132**	**9.9%**	**13.0%**	**13.5%**	**13.6%**
ExUrban									
	ExUrban Other	0	9	10	10	0.0%	1.0%	1.0%	1.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	8	8	8	0.0%	0.8%	0.8%	0.8%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	1	17	22	0.0%	0.1%	1.8%	2.2%
	Totals	**0**	**19**	**35**	**40**	**0.0%**	**1.9%**	**3.6%**	**4.1%**
Transportation									
	Public Road	11	20	20	20	1.2%	2.1%	2.1%	2.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	7	0	0	0	0.7%	0.0%	0.0%	0.0%
	Totals	**18**	**20**	**20**	**20**	**1.9%**	**2.1%**	**2.1%**	**2.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	40	60	0.0%	0.0%	5.4%	8.2%	0.0%	5.4%	2.9%	8.2%
	Pivot	0	0	0	47	0.0%	0.0%	0.0%	6.3%	0.0%	0.0%	6.3%	6.3%
	Flood	384	255	215	18	45.4%	32.9%	28.7%	2.5%	-12.5%	-4.2%	-26.2%	-42.9%
	Totals	**384**	**255**	**255**	**125**	**45.4%**	**32.9%**	**34.1%**	**17.0%**	**-12.5%**	**1.2%**	**-17.0%**	**-28.3%**

Non-Irrigated												
Multi-Use	441	446	463	478	52.1%	57.4%	61.9%	64.9%	5.3%	4.5%	3.0%	12.8%
Hay/Pasture	21	75	30	133	2.5%	9.7%	4.0%	18.1%	7.1%	-5.7%	14.0%	15.5%
Totals	**462**	**521**	**493**	**611**	**54.6%**	**67.1%**	**65.9%**	**83.0%**	**12.5%**	**-1.2%**	**17.0%**	**28.3%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	2.0	65.1	19.0	0.0	**86.1**
Acres/Valley Mile	1.2	37.9	11.0	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.27	0.07%	0.09	0.01	0.00	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County	Park	**Upstream River Mile**	493.6
Classification	UA: Unconfined anabranching	**Downstream River Mile**	488.3
General Location	To below Mission Creek	**Length**	5.30 mi (8.53 km)

General Comments Reach PC18, located near Mission Creek in Park County, provides an example of both active (structure-related) and passive side channel loss, and also demonstrates CES data gaps in Park County.

Narrative Summary

Reach PC18 is located in Park County, downstream of Livingston at Mission Creek. It is 5.3 miles long, extending from RM 488.2 to RM 493.5. Reach PC 18 is an Unconfined Anabranching (UA) reach type. In the uppermost portion of the Reach (RM 492.5-493.5), the river flows along bluffs of the Fort Union Formation, which is made up of massive cliff-forming sedimentary rocks. The south side of the river consists primarily of young river deposits that form the modern valley bottom and low terraces. Sheep Mountain Fishing Access Site is located at RM 491.5. Just upstream of the fishing access site, the Middle Windsor Ditch diverts water off of a side channel.

In 2001, there was 9,650 feet of rock riprap in the reach and by 2011 that had expanded to 11,486 feet. Similarly, the extent of flow deflectors expanded from 1,710 feet to 3,370 feet from 2001 to 2011. Approximately 27 percent of the total bankline was armored in 2011. There is also one floodplain dike on the south floodplain near RM 492 that is about 3,400 feet long.

Over two miles of side channel have been blocked by dikes in Reach PC18. All of these lost side channels are located in the lower end of the reach below the mouth of Mission Creek. On the order of 3,370 feet were blocked prior to 1950, and about 8,000 feet since then.

Land uses in Reach PC18 are almost entirely agricultural, with historic flood irrigation converting to sprinkler and pivot, and some exurban development since 1950. There are still 302 acres of ground under flood irrigation in the reach. The major land use in the reach, however, is non-irrigated agriculture. There is one series of corrals associated with an animal holding facility that is within 200 feet of an abandoned channel at RM 490.3. Exurban Residential land use has expanded from zero acres in the1950s to 155 acres in 2011.

About 580 acres of wetlands have been mapped in Reach PC18, most of which are emergent marshes and wet meadows. Most of these wetlands are on the south side of the river in non-irrigated hay pastures or multi-use riparian bottoms.

Reach PC18 has 17 acres of Russian olive, which is the most of in any reach in Park County. This Russian olive is concentrated in one area on the south floodplain at RM 492.8; this area also has extensive mapped emergent wetlands.

This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,720 cfs to 1,560 cfs with human development, a reduction of 9.3 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC18 include:
•Blocked side channels that are thousands of feet long.
•Concentrated Russian olive infestation within mapped emergent wetland.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC18 include:
•Side channel restoration at RM 490R
•CMZ Management due to current restriction of 14 percent of the Channel Migration Zone
•Russian olive removal
•Nutrient management at corrals that are part of an animal handling facility at RM 490.3L
•Bank Stabilization Recommended due to the extent of armoring in the reach (27 percent armored banks)
•Irrigation diversion structure management at Middle Windsor Ditch diversion

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	123.9	13.0

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	11,400	22,400	28,100	31,700	38,900	41,800	48,500	1,720	1,760
Regulated	11,100	22,000	27,800	31,400	38,600	41,600	48,400	1,560	1,680
% Change	-2.63%	-1.79%	-1.07%	-0.95%	-0.77%	-0.48%	-0.21%	-9.30%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
1948	NA		DNR B/W			
1954	NA		DNR B/W			
1965	NA		DNR B/W			
1973	NA		DNR B/W			
1976	NA		DNR B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2005	USDA FSA		NAIP Color			
2007	Wolpert??		Color			
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

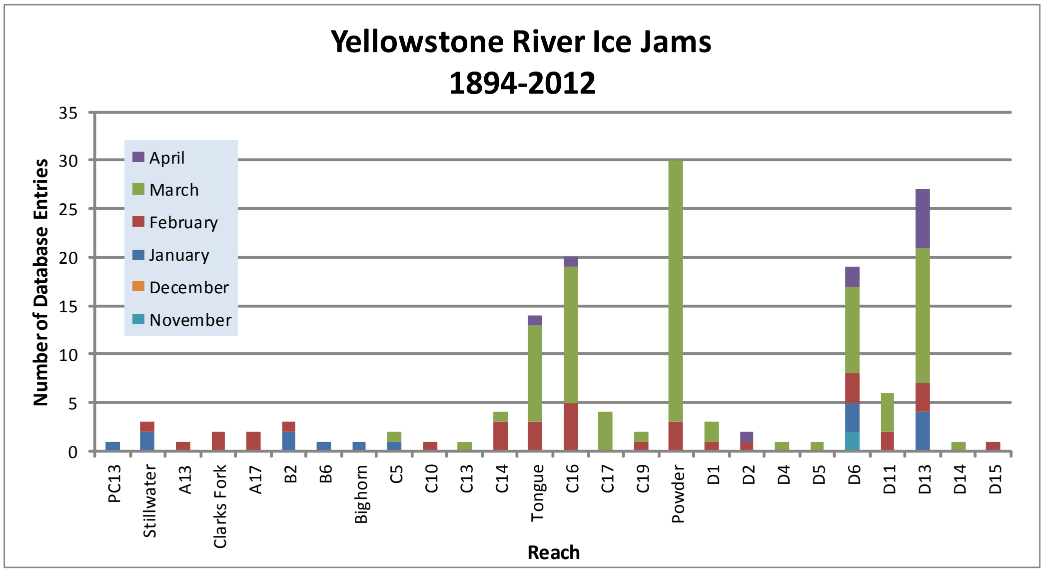
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	9,650	17.3%	11,486	20.6%	1,836
	Flow Deflectors	1,170	2.1%	1,352	2.4%	182
	Between Flow Deflectors	544	1.0%	2,110	3.8%	1,566
	Feature Type Totals	**11,364**	**20.4%**	**14,949**	**26.8%**	**3,584**
Floodplain Control						
	Floodplain Dike/Levee	3,339	6.0%	3,319	6.0%	-19
	Feature Type Totals	**3,339**	**6.0%**	**3,319**	**6.0%**	**-19**
	Reach Totals	**14,703**	**26.4%**	**18,268**	**32.8%**	**3,565**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	27,144	39,797	2.47	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	27,886	27,224	1.98	1950 to 2001:	-19.86%
Change 1950 - 2001	**742**	**-12,573**	**-0.49**		

Length of Side Channels Blocked

Pre-1950s (ft)	3,369
Post-1950s (ft)	7,999

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
266	532	1,087	117	11%	277	53	19%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Non-Irrigated	5	0.4%
	Irrigated	113	8.3%
RipRap			
	Irrigated	35	2.6%
	Exurban Residential	7	0.5%
	Canal	21	1.6%
Flow Deflectors			
	Other Infrastructure	3	0.2%
	Totals	**185**	**13.5%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
43.8	0.0	13.5	31.1	1.8

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	23	23	23	23	0.6%	0.6%	0.6%	0.6%
	Agricultural Roads	0	0	6	6	0.0%	0.0%	0.2%	0.2%
	Other Infrastructure	64	92	131	142	1.7%	2.4%	3.5%	3.7%
	Totals	**86**	**115**	**160**	**171**	**2.3%**	**3.0%**	**4.2%**	**4.5%**
Agricultural Land									
	Non-Irrigated	1,728	1,663	1,671	1,885	45.6%	43.8%	44.1%	49.7%
	Irrigated	1,365	1,351	1,124	843	36.0%	35.6%	29.6%	22.2%
	Totals	**3,093**	**3,014**	**2,795**	**2,728**	**81.6%**	**79.5%**	**73.7%**	**71.9%**
Channel									
	Channel	530	528	565	583	14.0%	13.9%	14.9%	15.4%
	Totals	**530**	**528**	**565**	**583**	**14.0%**	**13.9%**	**14.9%**	**15.4%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	12	12	0.0%	0.0%	0.3%	0.3%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	23	104	143	0.0%	0.6%	2.7%	3.8%
	Totals	**0**	**23**	**116**	**155**	**0.0%**	**0.6%**	**3.1%**	**4.1%**
Transportation									
	Public Road	62	24	47	47	1.6%	0.6%	1.2%	1.2%
	Interstate	0	67	88	88	0.0%	1.8%	2.3%	2.3%
	Railroad	21	21	21	21	0.6%	0.6%	0.6%	0.6%
	Totals	**84**	**112**	**155**	**155**	**2.2%**	**3.0%**	**4.1%**	**4.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	91	128	0.0%	0.0%	3.2%	4.7%	0.0%	3.2%	1.5%	4.7%
	Pivot	0	0	275	412	0.0%	0.0%	9.8%	15.1%	0.0%	9.8%	5.3%	15.1%
	Flood	1,365	1,351	759	303	44.1%	44.8%	27.1%	11.1%	0.7%	-17.7%	-16.0%	-33.0%
	Totals	**1,365**	**1,351**	**1,124**	**843**	**44.1%**	**44.8%**	**40.2%**	**30.9%**	**0.7%**	**-4.6%**	**-9.3%**	**-13.2%**

Non-Irrigated												
Multi-Use	1,487	1,399	1,459	1,410	48.1%	46.4%	52.2%	51.7%	-1.7%	5.8%	-0.5%	3.6%
Hay/Pasture	241	264	212	475	7.8%	8.8%	7.6%	17.4%	1.0%	-1.2%	9.8%	9.6%
Totals	**1,728**	**1,663**	**1,671**	**1,885**	**55.9%**	**55.2%**	**59.8%**	**69.1%**	**-0.7%**	**4.6%**	**9.3%**	**13.2%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	6.5	504.8	68.1	0.0	**579.4**
Acres/Valley Mile	1.4	105.6	14.3	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	16.66	0.79%	1.63	0.33	0.14	0.32

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County	Park	**Upstream River Mile**	488.3
Classification	CS: Confined straight	**Downstream River Mile**	485.4
General Location	To near Locke Cr	**Length**	2.90 mi (4.67 km)

General Comments

Narrative Summary

Reach PC19 is located in Park County, downstream of Livingston near Locke Creek. It is 2.9 miles long, and is a Confined Straight (CS) reach type indicating that it is highly confined between the valley wall to the north, and by the railroad/Interstate corridor to the south. The transportation corridor has isolated on the order of 40acres of historic floodplain from the river. These broad fields south of the river that are historic floodplain areas are now irrigated. The primary land use in the reach is agriculture, with about 200 acres each of flood, pivot, and sprinkler irrigation. More than half of the agricultural land is non-irrigated (~750 acres). In 1950, the transportation corridor footprint consumed about 50 acres in the reach, and that area was doubled with the construction of the Interstate in the late 1960s.

The stability of the reach is indicated by the fact that less than 3 percent of the bankline is armored. That 805 feet of armor was all constructed on the right bank sometime since 2001 where the river flows within a few hundred feet of the rail line. There are no side channels in the reach and the CMZ is relatively narrow.

Although the corridor confined and relatively narrow, there are about 50 acres of wetlands mapped in Reach PC19. These wetlands are consistently along low areas of the active riverbanks that support emergent and scrub/shrub wetland types. Only 0.03 acres of Russian olive was mapped in the reach.

This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events now considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,730 cfs to 1,560 cfs with human development, a reduction of 9.8 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC19 include:
•Corridor confinement by transportation infrastructure.
•Agricultural development and irrigation of historic floodplain area that has become isolated from the river by transportation infrastructure.

No reach-specific Practices were identified for Reach PC19.

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	121.0	18.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	11,400	22,400	28,100	31,700	38,900	41,800	48,500	1,730	1,760
Regulated	11,100	22,000	27,800	31,400	38,600	41,600	48,400	1,560	1,680
% Change	-2.63%	-1.79%	-1.07%	-0.95%	-0.77%	-0.48%	-0.21%	-9.83%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

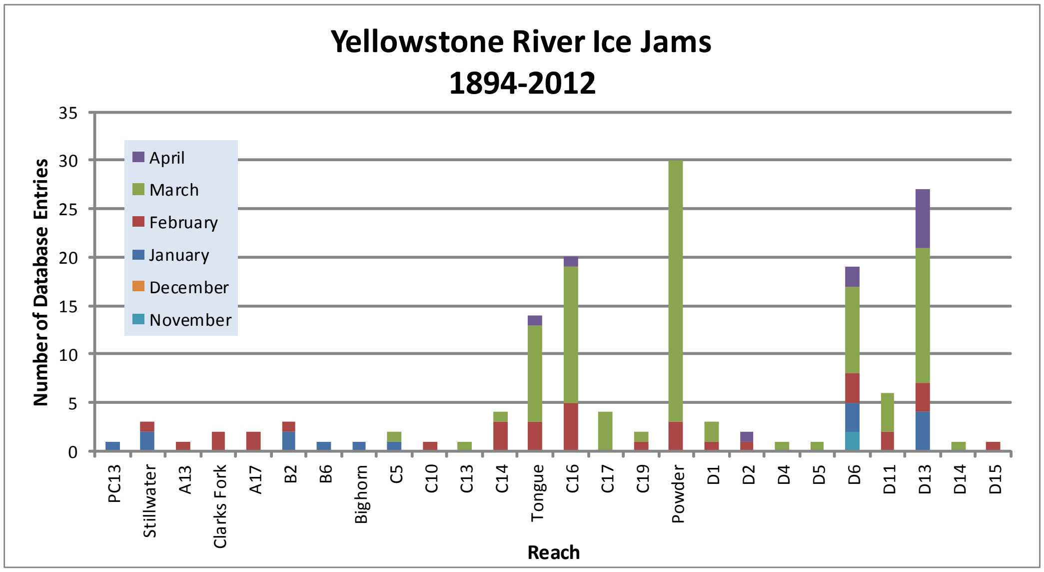
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	0	0.0%	805	2.8%	805
	Feature Type Totals		**0.0%**	**805**	**2.8%**	
	Reach Totals		**0.0%**	**805**	**2.8%**	

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	14,505		1.00	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	14,533		1.00	1950 to 2001:	0.00%
Change 1950 - 2001	**28**		**0.00**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
19	38	153	0	0%	0	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Non-Irrigated	2	1.4%
	Totals	**2**	**1.4%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
4.1	0.0	2.0	0.0	0.8

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	9	16	19	22	0.5%	1.0%	1.1%	1.3%
	Totals	**9**	**16**	**19**	**22**	**0.5%**	**1.0%**	**1.1%**	**1.3%**
Agricultural Land									
	Non-Irrigated	837	885	842	797	49.4%	52.2%	49.7%	47.0%
	Irrigated	686	613	611	654	40.5%	36.2%	36.1%	38.6%
	Totals	**1,522**	**1,498**	**1,453**	**1,450**	**89.8%**	**88.4%**	**85.7%**	**85.6%**
Channel									
	Channel	116	119	119	119	6.9%	7.0%	7.0%	7.0%
	Totals	**116**	**119**	**119**	**119**	**6.9%**	**7.0%**	**7.0%**	**7.0%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	1	0	0	0.0%	0.1%	0.0%	0.0%
	Totals	**0**	**1**	**0**	**0**	**0.0%**	**0.1%**	**0.0%**	**0.0%**
Transportation									
	Public Road	31	45	15	15	1.8%	2.7%	0.9%	0.9%
	Interstate	0	0	72	72	0.0%	0.0%	4.3%	4.3%
	Railroad	16	16	16	16	0.9%	0.9%	0.9%	0.9%
	Totals	**47**	**61**	**103**	**103**	**2.8%**	**3.6%**	**6.1%**	**6.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	201	201	0.0%	0.0%	13.9%	13.9%	0.0%	13.9%	0.0%	13.9%
	Pivot	0	0	26	241	0.0%	0.0%	1.8%	16.6%	0.0%	1.8%	14.8%	16.6%
	Flood	686	613	383	211	45.0%	40.9%	26.4%	14.6%	-4.1%	-14.5%	-11.8%	-30.5%
	Totals	**686**	**613**	**611**	**654**	**45.0%**	**40.9%**	**42.1%**	**45.1%**	**-4.1%**	**1.1%**	**3.0%**	**0.0%**

Non-Irrigated

Multi-Use	663	742	733	727	43.6%	49.5%	50.4%	50.1%	6.0%	0.9%	-0.3%	6.5%
Hay/Pasture	173	143	109	70	11.4%	9.6%	7.5%	4.8%	-1.8%	-2.0%	-2.7%	-6.6%
Totals	**837**	**885**	**842**	**797**	**55.0%**	**59.1%**	**57.9%**	**54.9%**	**4.1%**	**-1.1%**	**-3.0%**	**0.0%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	2.2	40.7	8.9	0.0	**51.9**
Acres/Valley Mile	0.8	15.2	3.3	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.03	0.08%	0.42	0.00	0.00	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County Park

Classification PCS: Partially confined straight

General Location East End

Upstream River Mile 485.4

Downstream River Mile 481

Length 4.40 mi (7.08 km)

General Comments

Narrative Summary

Reach PC20 is 4.4 miles long and flows through a narrow canyon known as East End just above Springdale. The reach is Partially Confined Straight (PCS); the river flows through a canyon that provides some curvature however that sinuosity is created by the canyon itself and does not reflect river meandering. Within Reach PC20, the river is closely bound by both the railroad line and Interstate. In places, the transportation infrastructure has been cut into the valley wall; in other areas it encroaches into the historic river floodplain. As a result, numerous slivers of historic floodplain area have become isolated from the river through the canyon, and most of these isolated floodplain areas are currently irrigated. Within the floor of the canyon, the river does show come migration, side channel formation, and habitat complexity, although those dynamics are relatively suppressed due to the natural and human-induced confinement.

Because of the moderately dynamic nature of the river and the encroachment by transportation infrastructure, there are over two miles of bank armor in Reach PC20, and about 1,100 feet of that armor was constructed since 2001. All of the armor is on the right bank of the river where the channel is against the railroad line. Over a quarter of the banks are armored.

The primary land use in Reach PC20 is non-irrigated agriculture, although there are 79 acres of ground under sprinkler irrigation, and 115 acres under pivot. All of the irrigation is well out of the Channel Migration Zone (CMZ).

Over 100 acres of wetlands have been mapped in Reach PC20 and there is some minor Russian olive present. All of the wetlands are in the active river corridor, on low surfaces that host emergent and scrub/shrub wetland types.

This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,730 cfs to 1,570 cfs with human development, a reduction of 9.3 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC20 include:
•Corridor confinement by transportation infrastructure.
•Agricultural development and irrigation of historic floodplain area that has become isolated from the river by transportation infrastructure.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC20 include:
•CMZ Management due to current restriction of 11 percent of the Channel Migration Zone
•Bank Stabilization Recommended due to 27 percent of banks being armored in reach

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	116.6	21.2

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	11,400	22,400	28,100	31,700	38,900	41,800	48,500	1,730	1,760
Regulated	11,100	22,000	27,800	31,400	38,600	41,600	48,400	1,570	1,680
% Change	-2.63%	-1.79%	-1.07%	-0.95%	-0.77%	-0.48%	-0.21%	-9.25%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

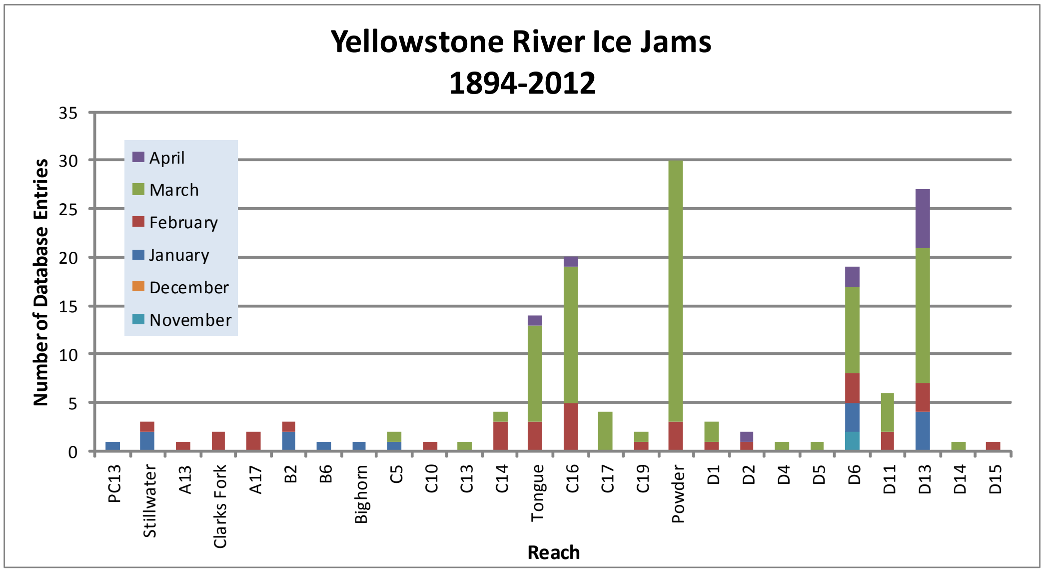
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	11,665	24.6%	12,764	27.0%	1,099
	Flow Deflectors	0	0.0%	56	0.1%	56
	Feature Type Totals	**11,665**	**24.6%**	**12,820**	**27.1%**	**1,155**
Floodplain Control						
	Floodplain Dike/Levee	3,181	6.7%	3,181	6.7%	0
	Feature Type Totals	**3,181**	**6.7%**	**3,181**	**6.7%**	**0**
	Reach Totals	**14,846**	**31.4%**	**16,001**	**33.8%**	**1,155**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	23,758	10,972	1.46	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	23,666	15,234	1.64	1950 to 2001:	12.44%
Change 1950 - 2001	**-92**	**4,262**	**0.18**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
142	284	539	57	11%	43	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Railroad	59	10.1%
	Non-Irrigated	8	1.4%
	Totals	**67**	**11.5%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	27	33	60	72	1.1%	1.3%	2.4%	2.8%
	Totals	**27**	**33**	**60**	**72**	**1.1%**	**1.3%**	**2.4%**	**2.8%**
Agricultural Land									
	Non-Irrigated	2,032	1,987	1,819	1,784	79.5%	77.7%	71.2%	69.8%
	Irrigated	133	117	193	203	5.2%	4.6%	7.6%	8.0%
	Totals	**2,166**	**2,104**	**2,012**	**1,987**	**84.7%**	**82.3%**	**78.7%**	**77.8%**
Channel									
	Channel	281	312	333	346	11.0%	12.2%	13.0%	13.5%
	Totals	**281**	**312**	**333**	**346**	**11.0%**	**12.2%**	**13.0%**	**13.5%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	54	0	13	13	2.1%	0.0%	0.5%	0.5%
	Interstate	0	81	112	112	0.0%	3.2%	4.4%	4.4%
	Railroad	28	26	26	26	1.1%	1.0%	1.0%	1.0%
	Totals	**82**	**107**	**151**	**151**	**3.2%**	**4.2%**	**5.9%**	**5.9%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	79	79	0.0%	0.0%	3.9%	4.0%	0.0%	3.9%	0.0%	4.0%
	Pivot	0	0	105	115	0.0%	0.0%	5.2%	5.8%	0.0%	5.2%	0.6%	5.8%
	Flood	133	117	9	9	6.2%	5.6%	0.5%	0.5%	-0.6%	-5.1%	0.0%	-5.7%
	Totals	**133**	**117**	**193**	**203**	**6.2%**	**5.6%**	**9.6%**	**10.2%**	**-0.6%**	**4.0%**	**0.6%**	**4.1%**

Non-Irrigated												
Multi-Use	1,998	1,934	1,788	1,766	92.2%	91.9%	88.8%	88.9%	-0.3%	-3.1%	0.0%	-3.4%
Hay/Pasture	34	53	31	18	1.6%	2.5%	1.5%	0.9%	0.9%	-1.0%	-0.6%	-0.7%
Totals	**2,032**	**1,987**	**1,819**	**1,784**	**93.8%**	**94.4%**	**90.4%**	**89.8%**	**0.6%**	**-4.0%**	**-0.6%**	**-4.1%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	1.0	64.3	45.8	0.0	**111.1**
Acres/Valley Mile	0.3	15.8	11.2	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.22	0.05%	0.12	0.01	0.02	0.04

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Yellowstone River Reach Narratives — Reach PC21

County	Park	**Upstream River Mile**	481
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	478.8
General Location	To Springdale	**Length**	2.20 mi (3.54 km)

General Comments

Narrative Summary

Reach PC21 is the downstream-most reach in Park County, emerging from a narrow canyon just above Springdale. The reach is 2.2 miles long, and is classified as Partially Confined Anabranching, reflecting some influence of the valley wall on channel form coupled by islands and side channels. At the upstream end of the reach, the Hunters Hot Springs Canal Diversion diverts water along the left bank of the river where it flows along the valley wall. This canal carries water about 11 miles down the river valley.

Reach PC21 is fairly heavily armored, with over a mile of bank armor in the reach, and most of that is rock riprap. Most of the armor is on the right bank against the railroad line, but there is also armor protecting the Hunters Hot Springs Canal Diversion as well as hayfields along the left bank. In the lower end of the reach the left bank is a high terrace that has bedrock exposed at its toe.

The primary land use in Reach PC21 is non-irrigated agriculture, although there are 266 acres of ground under pivot irrigation. All of the pivot irrigation is well out of the Channel Migration Zone (CMZ). The Springdale Bridge Fishing Access Site is located in at the downstream end of the reach at Springdale Bridge. The bridge narrows the CMZ width from about 2,500 feet upstream to 1,000 feet downstream of the structure. Just upstream of the bridge, there are remnants of an older bridge, including a large pier in the river. Bedrock is exposed in the riverbed just upstream of the bridge.

About 90 acres of wetlands have been mapped in Reach PC21 and about 18 of those acres consist of emergent wetlands in low historic floodplain area that has been isolated from the river by the railroad and interstate. Although the Russian olive mapping shows 0.2 acres of RO in the reach, some of that had been eroded out by the river by fall 2011.

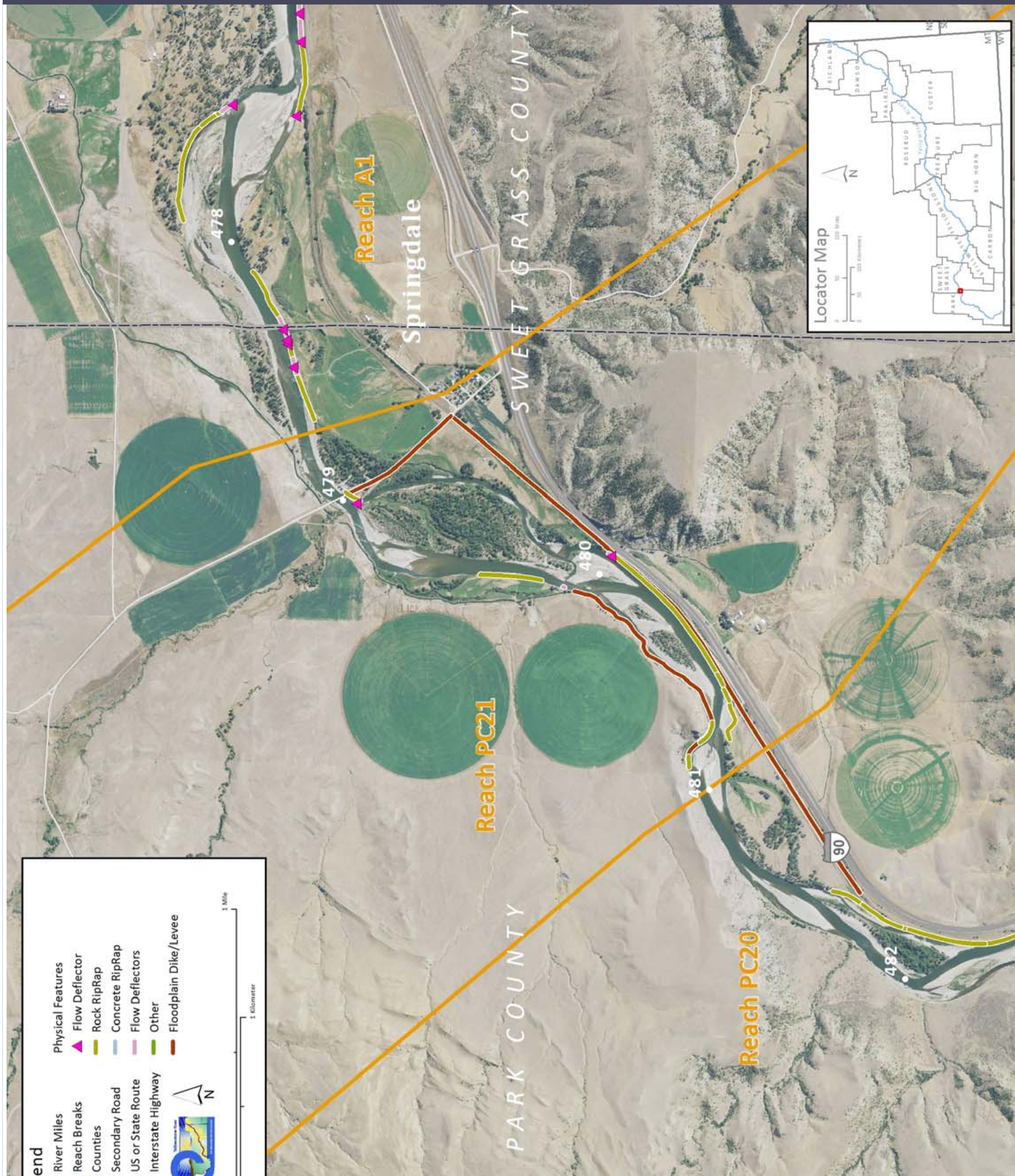
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,730 cfs to 1,570 cfs with human development, a reduction of 9.3 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC21 include:
•Corridor confinement by transportation infrastructure.
•Emergent wetlands located in isolated floodplain area.
•Narrowing of CMZ by Springdale Bridge.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC21 include:
•CMZ Management due to current restriction of 19 percent of the Channel Migration Zone
•Bank Stabilization Recommended Practices due to 27 percent of banks being armored in reach
•Irrigation diversion structure management at Hunters Hot Springs Canal diversion.

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	114.4	25.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	11,400	22,400	28,100	31,700	38,900	41,800	48,500	1,730	1,760
Regulated	11,100	22,000	27,800	31,400	38,600	41,600	48,400	1,570	1,680
% Change	-2.63%	-1.79%	-1.07%	-0.95%	-0.77%	-0.48%	-0.21%	-9.25%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2005	NAIP	08/25/2005	color	1-meter pixels	6192500	2390
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

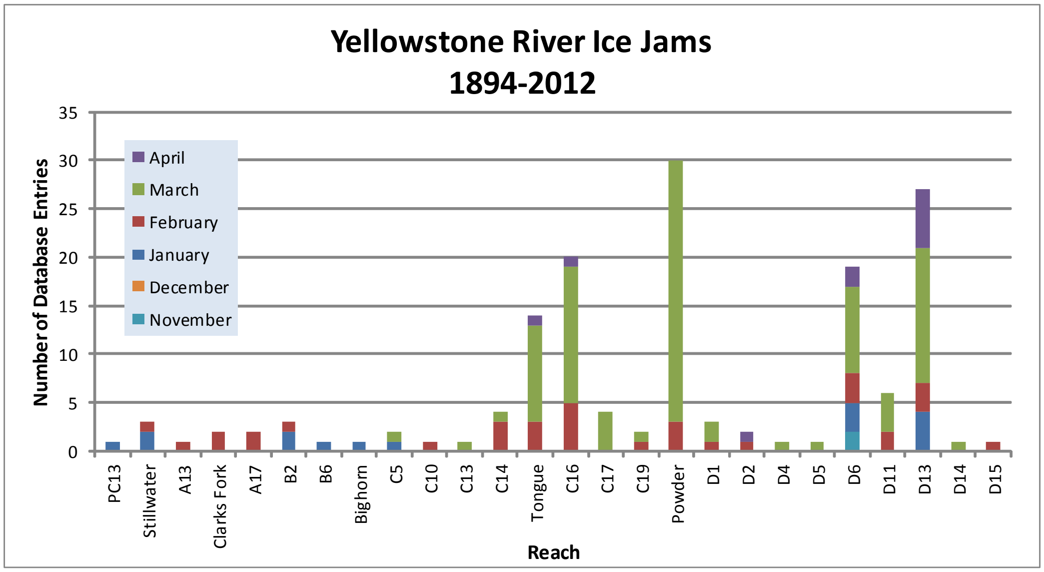
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	6,101	25.5%	6,270	26.2%	169
	Flow Deflectors	60	0.3%	123	0.5%	62
	Feature Type Totals	**6,161**	**25.7%**	**6,393**	**26.7%**	**232**
Floodplain Control						
	Floodplain Dike/Levee	15,601	65.1%	15,612	65.1%	12
	Feature Type Totals	**15,601**	**65.1%**	**15,612**	**65.1%**	**12**
	Reach Totals	**21,762**	**90.8%**	**22,005**	**91.8%**	**244**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	11,658	14,314	2.23	1950 to 1976:	
1976	1,552			1976 to 1995:	
1995				1995 to 2001:	
2001	11,983	14,978	2.25	1950 to 2001:	1.00%
Change 1950 - 2001	**325**	**664**	**0.02**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
131	261	328	56	17%	11	9	82%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	25	7.3%
RipRap			
	Railroad	30	8.7%
	Irrigated	11	3.1%
	Totals	**65**	**19.2%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
9.5	0.0	0.0	6.7	22.9

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	18	20	20	20	1.5%	1.6%	1.6%	1.6%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	0	17	28	54	0.0%	1.4%	2.3%	4.4%
	Totals	**18**	**37**	**48**	**74**	**1.5%**	**3.0%**	**3.9%**	**6.0%**
Agricultural Land									
	Non-Irrigated	770	623	555	496	63.0%	51.0%	45.4%	40.6%
	Irrigated	148	264	291	336	12.1%	21.6%	23.8%	27.5%
	Totals	**918**	**887**	**846**	**832**	**75.1%**	**72.6%**	**69.2%**	**68.1%**
Channel									
	Channel	235	231	249	237	19.3%	18.9%	20.4%	19.4%
	Totals	**235**	**231**	**249**	**237**	**19.3%**	**18.9%**	**20.4%**	**19.4%**
ExUrban									
	ExUrban Other	0	0	7	7	0.0%	0.0%	0.5%	0.5%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	13	13	15	15	1.0%	1.0%	1.2%	1.2%
	Totals	**13**	**13**	**21**	**21**	**1.0%**	**1.0%**	**1.7%**	**1.7%**
Transportation									
	Public Road	28	3	6	6	2.3%	0.2%	0.5%	0.5%
	Interstate	0	43	43	43	0.0%	3.6%	3.6%	3.6%
	Railroad	10	9	9	9	0.8%	0.7%	0.7%	0.7%
	Totals	**38**	**55**	**58**	**58**	**3.1%**	**4.5%**	**4.8%**	**4.8%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	9	9	0.0%	0.0%	1.1%	1.1%	0.0%	1.1%	0.0%	1.1%
	Pivot	0	155	224	257	0.0%	17.5%	26.5%	30.8%	17.5%	9.0%	4.4%	30.8%
	Flood	148	109	58	70	16.1%	12.3%	6.8%	8.4%	-3.8%	-5.5%	1.6%	-7.7%
	Totals	**148**	**264**	**291**	**336**	**16.1%**	**29.8%**	**34.4%**	**40.3%**	**13.6%**	**4.6%**	**5.9%**	**24.2%**

Non-Irrigated

Multi-Use	540	518	506	477	58.8%	58.4%	59.8%	57.3%	-0.4%	1.4%	-2.5%	-1.5%
Hay/Pasture	230	105	49	20	25.1%	11.9%	5.8%	2.4%	-13.2%	-6.0%	-3.5%	-22.7%
Totals	**770**	**623**	**555**	**496**	**83.9%**	**70.2%**	**65.6%**	**59.7%**	**-13.6%**	**-4.6%**	**-5.9%**	**-24.2%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	1.9	61.8	25.6	0.0	**89.3**
Acres/Valley Mile	1.0	31.4	13.0	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.17	0.23%	1.07	0.03	0.02	0.06

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

County	Sweet Grass	**Upstream River Mile**	478.8
Classification	PCB: Partially confined braided	**Downstream River Mile**	475.4
General Location	Springdale	**Length**	3.40 mi (5.47 km)

General Comments Springdale: Low primary sinuosity; large open bar area; extensive armoring

Narrative Summary

Reach A1 is located just downstream of the Springdale Bridge in western-most Sweet Grass County. It is a Partially Confined Braided (PCB) reach type, indicating some influence of the valley wall on river geomorphology, as well as abundant un-vegetated mid-channel bars. The reach is 3.4 miles long. This reach is most prominently characterized by a large meander located at RM 478 that has been very dynamic over recent years. The meander bend has repeatedly migrated to the north and then cut off, leaving broad open gravel bars and a wide active channel corridor. The bendway has been heavily armored on its apex, and partially armored on its downstream limb. With all of the changes at this meander, there has been a net gain of total channel area in the reach of about 50 acres since 1950.

There are about 6,800 feet of rock riprap in the reach, over 1,500 feet of which was constructed since 2001. Several flow deflectors have been eroded out in Reach A1 since 2001. About 25 percent of the bankline was armored as of 2011. There are also over 6,800 feet of mapped transportation encroachment in the river corridor, most of which is the rail line that follows the south bank.

Although the rail line runs along the edge of the river, it is situated on higher terraces and as such has not isolated any 100-year historic floodplain area. However, about 9 percent of the total Channel Migration Zone (CMZ) footprint has become restricted, and these restrictions are due to armoring against both the rail line and irrigated fields. This demonstrates how terraces that may be out of the 100-year floodplain can still be prone to erosion and thus within the CMZ.

The primary land use in the reach is non-irrigated agriculture (~1,100 acres), although there are about 650 acres under some form of irrigation. Pivot irrigation has expanded from 0 acres in 1950 to 302 acres in 2011. Similarly, sprinkler irrigation has expanded from 0 to 250 acres during the same time frame, and the extent of flood irrigated lands dropped from 803 to 123 acres over those 61 years. About 46 acres of land under sprinkler and 10 acres of land under pivot are located within the CMZ.

About 120 acres of wetland have been mapped in the reach, with most of that (84 acres) emergent wetland marsh that is located primarily in the active stream corridor. About 20 acres of wetland have been isolated from the corridor by the rail line near RM 477.8. About 0.7 acres of Russian olive have been mapped in the reach, and these trees are dispersed throughout the corridor.

Hydraulic modeling of the reach shows an extensive network of floodplain channels on the floodplain in Reach A1 that creates some avulsion risk north of the river. Much of the armoring on the large meander at RM 478 has reduced the risk of an avulsion and potential bypass of the Prather Mayborn Westfall Ditch Diversion. In addition, one of the overflow channels has been allowed to activate, which has reduced the potential for additional avulsions. The strategic allowance of channel migration and secondary channel activation has prevented the creation of a severe pinch point at RM 477.4 that may have created long-term instability in the reach.

A large dike at RM 476.7 blocks a ~3,000-foot long side channel and focuses the river towards the south bank and the Prather Mayborn Westfall Ditch Diversion. Although the dike blocks the head of the channel, it is still seasonally accessed by other overflow points from the main river.

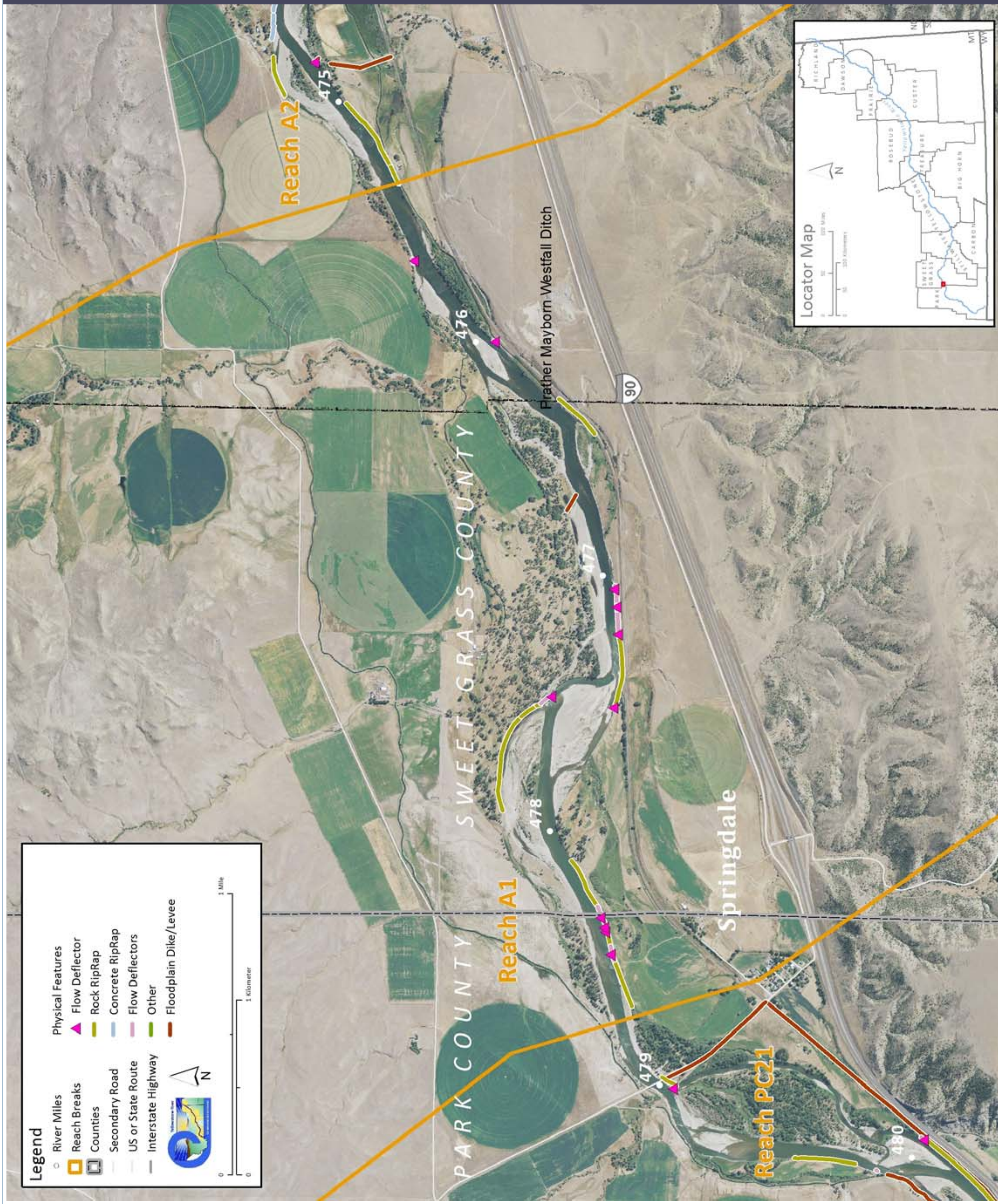
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,750 cfs to 1,570 cfs with human development, a reduction of 10.3 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A1 include:
•Strategic allowance of side channel activation to reduce overall avulsion risk
•Isolation of emergent wetlands by transportation infrastructure
•Blockage of a 3,000-foot long side channel to focus flows to a diversion structure.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A1 include:
•CMZ management due to level of restriction and avulsion risks on north floodplain
•Bank Stabilization Recommended Practices due to current extent of bank armoring (25 percent of total bankline)
•Irrigation diversion structure management at Prather Mayborn Westfall
•Wetland management/restoration due to high wetland concentrations

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	111.0	27.8

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	11,900	23,300	29,200	32,900	40,300	43,400	50,300	1,750	1,760
Regulated	11,500	22,900	28,800	32,500	40,000	43,200	50,100	1,570	1,680
% Change	-3.36%	-1.72%	-1.37%	-1.22%	-0.74%	-0.46%	-0.40%	-10.29%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	5-Jul-48	B/W	1:23,600	6192500	9810
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS-DOQ	23-Aug-97	B/W	1:24,000	6192500	4840
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2005	NAIP	08/25/2005	color	1-meter pixels	6192500	2390
2007	Woolpert	29-Jun-05	Color	1:	6192500	
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	5,160	14.5%	6,839	19.2%	1,678
	Flow Deflectors	1,406	3.9%	573	1.6%	-832
	Between Flow Deflectors	995	2.8%	1,518	4.3%	523
	Feature Type Totals	**7,561**	**21.2%**	**8,930**	**25.1%**	**1,370**
Floodplain Control						
	Transportation Encroachment	6,845	19.2%	6,845	19.2%	0
	Floodplain Dike/Levee	331	0.9%	331	0.9%	0
	Feature Type Totals	**7,176**	**20.1%**	**7,176**	**20.1%**	**0**
	Reach Totals	**14,737**	**41.3%**	**16,107**	**45.2%**	**1,370**

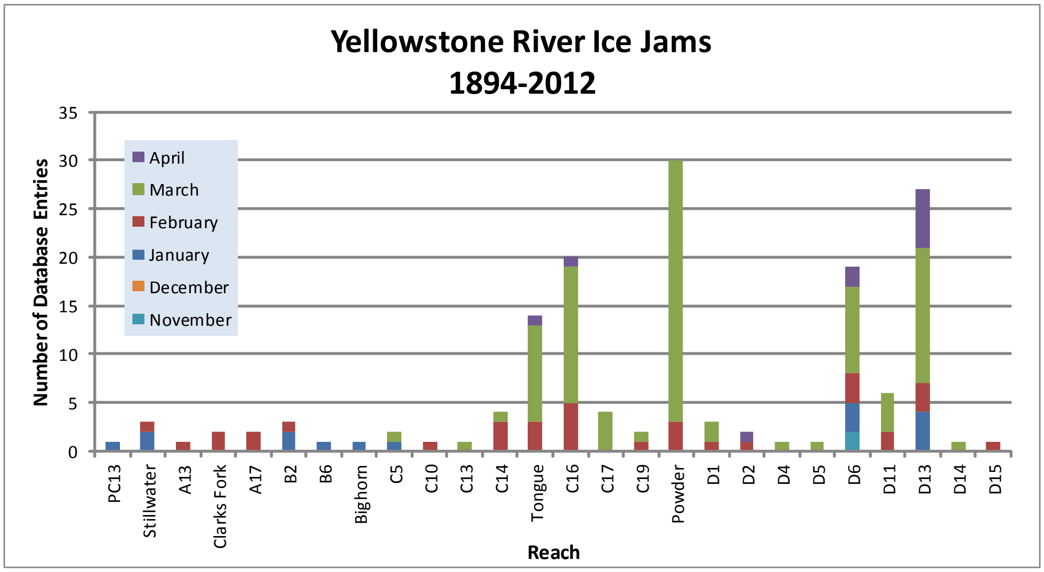
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	0	522	0	0	0	895	0	0
Totals	**0**	**522**	**0**	**0**	**0**	**895**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	18,968	6,571	1.35	1950 to 1976:	9.83%
1976	18,838	9,020	1.48	1976 to 1995:	25.57%
1995	17,553	15,040	1.86	1995 to 2001:	-9.38%
2001	17,825	12,169	1.68	1950 to 2001:	24.97%
Change 1950 - 2001	**-1,143**	**5,598**	**0.34**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	2,970

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	344		422	
Total Floodplain Area (Ac)	344		435	
Total Isolated (Ac)	**0**	**0.0%**	**13**	**7.4%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	5	0	**5**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
190	379	582	82	14%	157	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	2	0.3%
RipRap/Flow Deflectors			
	Railroad	28	3.8%
	Irrigated	30	4.0%
RipRap			
	Railroad	6	0.8%
	Totals	**66**	**8.9%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
15.7	46.1	10.0	0.0	9.8

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	16	16	16	16	0.7%	0.7%	0.7%	0.7%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	36	33	65	93	1.5%	1.4%	2.8%	4.0%
	Totals	**52**	**50**	**81**	**109**	**2.2%**	**2.1%**	**3.5%**	**4.7%**
Agricultural Land									
	Non-Irrigated	1,189	1,207	1,152	1,112	51.3%	52.1%	49.7%	47.9%
	Irrigated	803	766	700	678	34.7%	33.1%	30.2%	29.3%
	Totals	**1,993**	**1,973**	**1,852**	**1,790**	**86.0%**	**85.1%**	**79.9%**	**77.2%**
Channel									
	Channel	220	243	298	332	9.5%	10.5%	12.9%	14.3%
	Totals	**220**	**243**	**298**	**332**	**9.5%**	**10.5%**	**12.9%**	**14.3%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	5	5	5	5	0.2%	0.2%	0.2%	0.2%
	Totals	**5**	**5**	**5**	**5**	**0.2%**	**0.2%**	**0.2%**	**0.2%**
Transportation									
	Public Road	28	28	14	14	1.2%	1.2%	0.6%	0.6%
	Interstate	0	0	48	48	0.0%	0.0%	2.1%	2.1%
	Railroad	20	20	20	20	0.8%	0.8%	0.8%	0.8%
	Totals	**48**	**48**	**82**	**82**	**2.1%**	**2.1%**	**3.5%**	**3.5%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	260	254	0.0%	0.0%	14.0%	14.2%	0.0%	14.0%	0.2%	14.2%
	Pivot	0	0	287	302	0.0%	0.0%	15.5%	16.9%	0.0%	15.5%	1.4%	16.9%
	Flood	803	766	153	123	40.3%	38.8%	8.3%	6.8%	-1.5%	-30.6%	-1.4%	-33.5%
	Totals	**803**	**766**	**700**	**678**	**40.3%**	**38.8%**	**37.8%**	**37.9%**	**-1.5%**	**-1.1%**	**0.1%**	**-2.4%**

Non-Irrigated													
	Multi-Use	1,119	1,059	1,100	1,046	56.2%	53.7%	59.4%	58.5%	-2.5%	5.7%	-0.9%	2.3%
	Hay/Pasture	70	147	52	65	3.5%	7.5%	2.8%	3.6%	3.9%	-4.6%	0.8%	0.1%
	Totals	**1,189**	**1,207**	**1,152**	**1,112**	**59.7%**	**61.2%**	**62.2%**	**62.1%**	**1.5%**	**1.1%**	**-0.1%**	**2.4%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.9	0.3	0.0	0.8	0.3	0.4	14.7	16.0	6.2
Max	20.0	11.9	5.3	219.1	149.9	171.1	14.7	29.8	26.6
Average	8.3	3.6	2.6	39.0	28.0	23.4	14.7	24.2	18.9
Sum	49.7	21.7	20.7	312.2	223.7	233.7	14.7	72.6	56.8

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	71.8
Channel to Riparian (acres)	26.4
Riparian Encroachment (acres)	**-45.5**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	7.4	84.3	38.0	0.0	**129.8**
Acres/Valley Mile	2.3	26.0	11.7	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.67	0.18%	1.19	0.03	0.03	0.01

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.

There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Sweet Grass	**Upstream River Mile**	475.4
Classification	UB: Unconfined braided	**Downstream River Mile**	468.5
General Location	Grey Bear fishing access	**Length**	6.90 mi (11.10 km)
General Comments	Grey Bear fishing access		

Narrative Summary

Reach A2 is 6.9 miles long and extends from about one mile below the Prather Mayborn Westfall Ditch Diversion to about a mile below the Grey Bear fishing access. Reach A2 is classified as Unconfined Braided (UB), indicating a relatively small influence of the valley wall on reach geomorphology as well as a preponderance of open gravel bars in the channel. Reach A2 has changed markedly since the 1950s due to loss of riparian forest and side channel length.

As a consequence of its unconfined and dynamic nature, there are over two miles of rock riprap in the reach that cover almost 18 percent of the total bankline. Of those 10,633 feet of rock riprap, 1,673 feet was constructed since 2001. The physical features mapping also indicated 945 feet of tree revetments in the reach in 2001, however these were not identified in the 2011 mapping. This is the most upstream-reach with mapped concrete rubble riprap; there are over 1,000 feet of concrete riprap on the left bank at RM 474.6.

Sometime prior to 1950, one 3,125 foot long channel was blocked at RM 473. In 1950, there were still over 6 miles of active anabranching channels, but by 2011 that side channel length had dropped to 4 miles, resulting in a 15 percent reduction of braiding parameter in the reach.

There is also intermittent transportation encroachment by the railroad on the south side of the river. The transportation encroachment, which is due to the rail line, extends over two miles along the south bank and isolates 23 acres of historic floodplain. Similarly, 140 acres of the natural Channel Migration Zone (CMZ) area has been restricted by bank armor and the railroad prism.

Floodplain turnover values show that turnover rates have dropped from 4.5 acres per year to 3.7 acres per year since 1976. The channel has also enlarged by over 30 acres as anabranching channels have consolidated into a larger single thread. About 23 acres of 100-year floodplain area has been isolated by dikes.

Land uses in Reach A2 are primarily agriculture, with about ½ of the total agricultural land in some form of irrigation. About 26 acres of the existing 5-year floodplain are currently under irrigation, most of which is in flood.

Over 300 acres of wetland have mapped in the reach, most of which is emergent marsh-type areas. About 40 acres of emergent wetland are in an area of historic floodplain isolated by the railroad at RM 471.2. Approximately ½ of an acre of Russian olive was mapped in Reach A2.

Reach A2 has had extensive riparian clearing over the last century. In 1950, there were 431 acres of closed timber in the reach, and that footprint had contracted to 275 acres by 2001. Almost 12 acres of riparian forest in the reach per valley mile have been identified as being at low risk of cowbird parasitism due to the distance of those areas from agricultural infrastructure.

This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,760 cfs to 1,580 cfs with human development, a reduction of 10.2 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A2 include:
•Blockage of over 3,000 feet of side channel prior to 1950
•Passive abandonment of over two additional miles of side channel since 1950.
•Loss of over 150 acres of closed timber since 1950, most of which is in the 5-year floodplain.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A2 include:
•Side Channel Restoration (RM 473)
•CMZ management due to extent of encroachment (140acres restricted)

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	104.1	31.2

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	11,900	23,300	29,200	32,900	40,300	43,400	50,300	1,760	1,760
Regulated	11,500	22,900	28,800	32,500	40,000	43,200	50,100	1,580	1,680
% Change	-3.36%	-1.72%	-1.37%	-1.22%	-0.74%	-0.46%	-0.40%	-10.23%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	5-Jul-48	B/W	1:23,600	6192500	9810
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	23-Aug-97	B/W	1:24,000	6192500	4840
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2005	NAIP	08/25/2005	color	1-meter pixels	6192500	2390
2007	Woolpert		Color		6192500	
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2011	NAIP	8/22/2011	Color	1-meter pixels	6192500	5480
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Tree Revetments	945	1.3%	0	0.0%	-945
	Rock RipRap	10,633	14.6%	12,306	16.9%	1,673
	Flow Deflectors	0	0.0%	154	0.2%	154
	Concrete RipRap	0	0.0%	1,015	1.4%	1,015
	Feature Type Totals	**11,578**	**15.9%**	**13,475**	**18.5%**	**1,897**
Floodplain Control						
	Transportation Encroachment	12,335	16.9%	12,335	16.9%	0
	Floodplain Dike/Levee	1,169	1.6%	1,169	1.6%	0
	Feature Type Totals	**13,504**	**18.5%**	**13,504**	**18.5%**	**0**
	Reach Totals	**25,082**	**34.4%**	**26,979**	**37.0%**	**1,897**

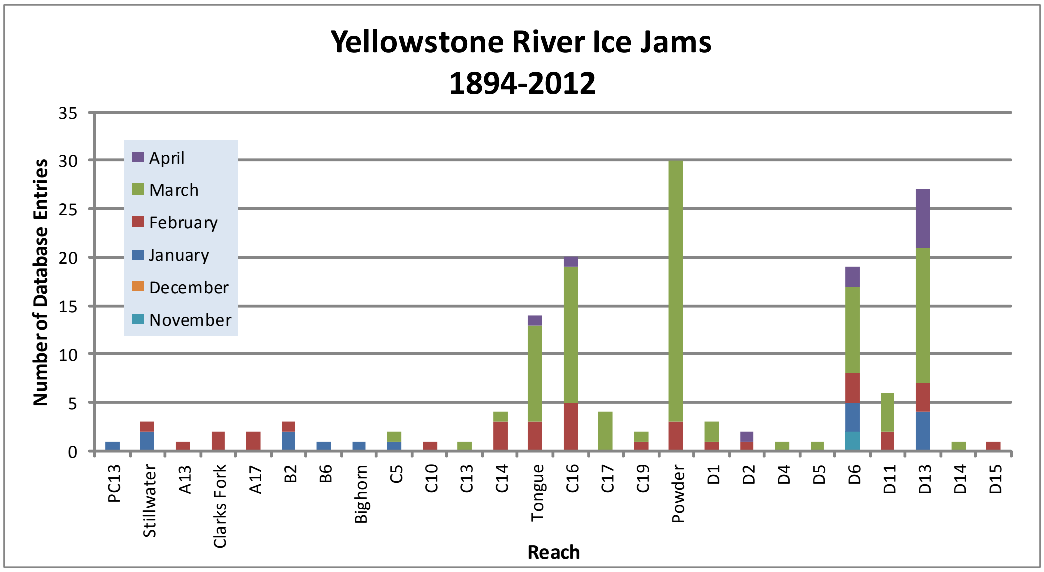
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	2,729	2,588	1,204	3,093	0	0	0	0
Rock RipRap	925	2,870	0	0	0	2,352	0	0
Totals	**3,654**	**5,458**	**1,204**	**3,093**	**0**	**2,352**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	38,287	33,176	1.87	1950 to 1976:	-7.11%
1976	36,820	27,020	1.73	1976 to 1995:	-4.04%
1995	36,672	24,344	1.66	1995 to 2001:	-4.33%
2001	36,483	21,587	1.59	1950 to 2001:	-14.72%
Change 1950 - 2001	**-1,805**	**-11,588**	**-0.27**		

Length of Side Channels Blocked

Pre-1950s (ft)	3,125
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	23	3.1%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	723		853	
Total Floodplain Area (Ac)	747		870	
Total Isolated (Ac)	**23**	**3.1%**	**16**	**4.1%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	26	0	0	**26**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
213	425	1,096	139	13%	130	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	19	1.5%
RipRap			
	Public Road	8	0.7%
	Other Infrastructure	13	1.1%
	Non-Irrigated	38	3.1%
	Irrigated	40	3.2%
	Canal	20	1.6%
	Agricultural Roads	3	0.3%
	Totals	**140**	**11.5%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
87.8	0.8	4.5	0.0	5.4

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	55	55	54	54	1.2%	1.2%	1.2%	1.2%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	86	119	129	163	1.9%	2.6%	2.8%	3.6%
	Totals	**141**	**174**	**183**	**218**	**3.1%**	**3.8%**	**4.0%**	**4.8%**
Agricultural Land									
	Non-Irrigated	1,699	1,339	1,531	1,505	37.3%	29.4%	33.6%	33.0%
	Irrigated	2,015	2,327	2,114	2,044	44.2%	51.1%	46.4%	44.9%
	Totals	**3,713**	**3,667**	**3,646**	**3,549**	**81.5%**	**80.5%**	**80.1%**	**77.9%**
Channel									
	Channel	608	622	575	623	13.4%	13.7%	12.6%	13.7%
	Totals	**608**	**622**	**575**	**623**	**13.4%**	**13.7%**	**12.6%**	**13.7%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	13	0.0%	0.0%	0.0%	0.3%
	Totals	**0**	**0**	**0**	**13**	**0.0%**	**0.0%**	**0.0%**	**0.3%**
Transportation									
	Public Road	52	52	49	49	1.1%	1.1%	1.1%	1.1%
	Interstate	0	0	62	62	0.0%	0.0%	1.4%	1.4%
	Railroad	40	40	40	40	0.9%	0.9%	0.9%	0.9%
	Totals	**92**	**91**	**150**	**150**	**2.0%**	**2.0%**	**3.3%**	**3.3%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	14	95	94	0.0%	0.4%	2.6%	2.6%	0.4%	2.2%	0.0%	2.6%
	Pivot	0	0	454	737	0.0%	0.0%	12.4%	20.8%	0.0%	12.4%	8.3%	20.8%
	Flood	2,015	2,314	1,565	1,213	54.3%	63.1%	42.9%	34.2%	8.8%	-20.2%	-8.7%	-20.1%
	Totals	**2,015**	**2,327**	**2,114**	**2,044**	**54.3%**	**63.5%**	**58.0%**	**57.6%**	**9.2%**	**-5.5%**	**-0.4%**	**3.3%**

Non-Irrigated

Multi-Use	1,400	1,127	1,374	1,348	37.7%	30.7%	37.7%	38.0%	-7.0%	6.9%	0.3%	0.3%
Hay/Pasture	298	212	158	156	8.0%	5.8%	4.3%	4.4%	-2.2%	-1.5%	0.1%	-3.6%
Totals	**1,699**	**1,339**	**1,531**	**1,505**	**45.7%**	**36.5%**	**42.0%**	**42.4%**	**-9.2%**	**5.5%**	**0.4%**	**-3.3%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.5	0.3	0.2	0.2	0.4	0.4	1.5	2.7	2.2
Max	20.4	13.8	13.6	56.5	51.0	35.6	18.5	42.6	39.2
Average	3.7	3.3	3.4	13.5	10.1	11.5	7.6	14.4	11.1
Sum	66.2	69.9	106.7	430.9	352.8	275.2	45.9	100.9	121.8

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	131.1
Channel to Riparian (acres)	100.5
Riparian Encroachment (acres)	**-30.6**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	17.0	257.8	80.9	0.0	**355.7**
Acres/Valley Mile	2.6	39.9	12.5	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.44	0.10%	1.38	0.12	0.04	0.04

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Sweet Grass	**Upstream River Mile**	468.5
Classification	PCB: Partially confined braided	**Downstream River Mile**	463
General Location	Upstream of Big Timber	**Length**	5.50 mi (8.85 km)
General Comments	Upstream of Big Timber; Hell Creek Formation valley wall		

Narrative Summary

Reach A3 is 5.5 miles long and is just located upstream of the town of Big Timber. It is classified as a Partially Confined Braided (PCB) reach type indicating some valley wall influence and relative extensive open gravel bars and low flow secondary channels. This reach shows the passive loss of miles of anabranching channel length since 1950, similar to Reach A2 just upstream. The river has converted from having more than one primary channel to having a dominant main thread with intermittent side channels.

About 12.5 percent of the banks in Reach A3 are armored, with the majority of that armor being rock riprap. Between 2001 and 2011, about 1,700 feet of new bank armor, of which 277 feet are flow deflectors, were installed. There are about 2,000 feet of floodplain dikes in the reach.

Similar to Reach A2 just upstream, this reach has experienced extensive loss of anabranching channel length since 1950. In 1950, the total length of anabranching channels was 6.7 miles, and by 2001 that length had dropped to 4.7 miles, resulting in a reduction in braiding parameter of 17 percent.

Reach A3 shows a reduction in floodplain turnover rates since 1976; prior to that time, average rates of turnover were 103 acres per year, and since that time the average rate of floodplain erosion by the river has been reduced to 65.4 acres per year.

Land use in Reach A3 is predominantly agricultural, with about ½ of all agricultural acreage in flood irrigation. Approximately 13 percent of the 5-year floodplain has been isolated in the reach. This isolation reflects the slight reduction in the magnitude flows in this reach due primarily to irrigation-related withdrawals upstream.

Over 600 acres of wetland have been mapped in Reach A3, most of which is emergent marshes and wet meadows on the south side of the river. The 4.6 acres of Russian olive mapped is dispersed throughout the riparian corridor.

Almost 50 acres of riparian forest per valley mile is considered at low risk of cowbird infestation due to its relative distance from agricultural infrastructure that provides cowbird foraging habitat.

This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 11,900 cfs to 11,500 cfs, a drop of about 3.4 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,770 cfs to 1,580 cfs with human development, a reduction of 11 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A3 include:
•Passive abandonment of over two miles of side channel since 1950.
•Conversion from a river channel with multiple large primary channels to a single main thread with small anabranches.
•Reduced floodplain turnover rates.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A3 include:
•Russian olive removal
•Wetland management/restoration due to high density of mapped emergent wetland

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	98.6	38.1

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	11,900	23,300	29,200	32,900	40,300	43,400	50,300	1,770	1,760
Regulated	11,500	22,900	28,800	32,500	40,000	43,200	50,100	1,580	1,680
% Change	-3.36%	-1.72%	-1.37%	-1.22%	-0.74%	-0.46%	-0.40%	-10.73%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	5-Jul-48	B/W	1:23,600	6192500	9810
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	8/23/97 - 8/28/97	B/W		6192500	4840
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2005	NAIP	08/25/2005	color	1-meter pixels	6192500	2390
2007	Woolpert	10/15/2007 - 11/2/2007	Color		6192500	
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	NAIP	8/22/2011	Color	1-meter pixels	6192500	5480
2013	NAIP	08/25/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	5,474	9.7%	6,765	12.0%	1,291
	Flow Deflectors	0	0.0%	277	0.5%	277
	Feature Type Totals	**5,474**	**9.7%**	**7,043**	**12.5%**	**1,568**
Floodplain Control						
	Floodplain Dike/Levee	1,949	3.5%	1,971	3.5%	22
	Feature Type Totals	**1,949**	**3.5%**	**1,971**	**3.5%**	**22**
	Reach Totals	**7,424**	**13.2%**	**9,013**	**16.0%**	**1,590**

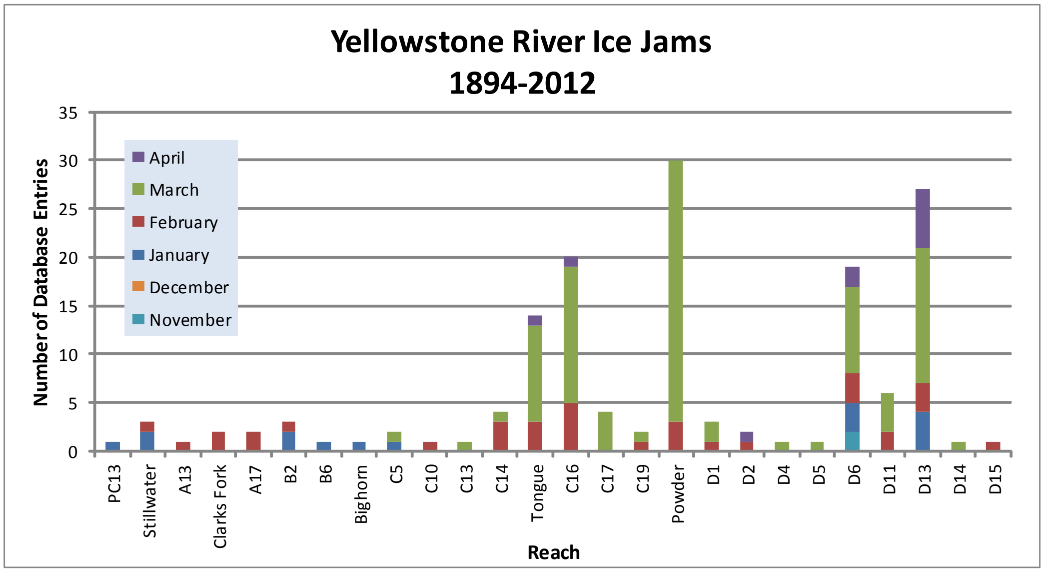
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	1,092	3,592	0	0	0	0	0	0
Tree Revetments	945	0	0	0	0	0	0	0
Totals	**2,037**	**3,592**	**0**	**0**	**0**	**0**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	27,827	35,195	2.26	1950 to 1976:	-4.80%
1976	28,236	32,641	2.16	1976 to 1995:	-14.37%
1995	28,264	23,919	1.85	1995 to 2001:	1.97%
2001	28,191	24,882	1.88	1950 to 2001:	-16.87%
Change 1950 - 2001	**364**	**-10,312**	**-0.38**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	864		882	
Total Floodplain Area (Ac)	864		895	
Total Isolated (Ac)	**0**	**0.0%**	**13**	**2.5%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	104	0	0	**104**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
217	435	994	67	7%	170	21	12%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Non-Irrigated	27	2.3%
RipRap			
	Non-Irrigated	40	3.4%
	Irrigated	33	2.8%
	Totals	**99**	**8.5%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
167.0	0.0	0.0	0.0	0.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	7	12	22	22	0.2%	0.3%	0.6%	0.6%
	Totals	**7**	**12**	**22**	**22**	**0.2%**	**0.3%**	**0.6%**	**0.6%**
Agricultural Land									
	Non-Irrigated	1,558	1,351	1,315	1,311	43.2%	37.4%	36.5%	36.3%
	Irrigated	1,492	1,627	1,668	1,670	41.4%	45.1%	46.3%	46.3%
	Totals	**3,050**	**2,977**	**2,984**	**2,981**	**84.6%**	**82.6%**	**82.7%**	**82.7%**
Channel									
	Channel	546	611	594	597	15.1%	16.9%	16.5%	16.6%
	Totals	**546**	**611**	**594**	**597**	**15.1%**	**16.9%**	**16.5%**	**16.6%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	1	3	4	4	0.0%	0.1%	0.1%	0.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	2	2	2	2	0.1%	0.1%	0.1%	0.1%
	Totals	**3**	**6**	**6**	**6**	**0.1%**	**0.2%**	**0.2%**	**0.2%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	1,492	1,627	1,668	1,670	48.9%	54.6%	55.9%	56.0%	5.7%	1.3%	0.1%	7.1%
	Totals	**1,492**	**1,627**	**1,668**	**1,670**	**48.9%**	**54.6%**	**55.9%**	**56.0%**	**5.7%**	**1.3%**	**0.1%**	**7.1%**

Non-Irrigated												
Multi-Use	1,249	1,114	1,226	1,224	41.0%	37.4%	41.1%	41.1%	-3.5%	3.7%	0.0%	0.1%
Hay/Pasture	308	237	89	87	10.1%	7.9%	3.0%	2.9%	-2.2%	-5.0%	-0.1%	-7.2%
Totals	**1,558**	**1,351**	**1,315**	**1,311**	**51.1%**	**45.4%**	**44.1%**	**44.0%**	**-5.7%**	**-1.3%**	**-0.1%**	**-7.1%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	1.1	0.0	1.4	0.5	0.1	0.9		2.0	9.0
Max	43.3	29.5	38.3	116.9	108.3	104.6		20.9	32.0
Average	15.8	4.4	10.8	12.8	13.2	20.5		11.5	17.9
Sum	142.0	74.5	97.3	358.4	410.6	347.8		23.0	53.7

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	83.0
Channel to Riparian (acres)	75.0
Riparian Encroachment (acres)	**-8.0**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	0.0
1950s Floodplain Mapped as 2011 Channel (Ac)	7.8
Total Recruitment (1950s to 2011)(Ac)	**7.8**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	5.1	558.7	86.5	0.0	**650.3**
Acres/Valley Mile	1.1	120.5	18.7	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	4.64	0.30%	0.64	1.66	0.92	0.67

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Sweet Grass	**Upstream River Mile**	463
Classification	UB: Unconfined braided	**Downstream River Mile**	459.7
General Location	Big Timber	**Length**	3.30 mi (5.31 km)
General Comments	To Boulder River confluence; encroachment at Big Timber; extensive armor		

Narrative Summary

Reach A4 is approximately 3.3 miles long, extending from near the Sweet Grass County Fairgrounds downstream to the Boulder River confluence. Reach A4 is very dynamic with active channel migration, threats to infrastructure, bank armor, flanked barbs, and active riparian recruitment on raw gravel bars. The most dynamic portion of the reach is upstream of the Highway 191 Bridge; in spring of 2013 a large meander formed a 1,500 foot long chute cutoff near the fairgrounds which abandoned about 3,500 feet of channel to the south.

About 19 percent of the banks in Reach A4 are armored, with the majority of that armor being rock riprap. Between 2001 and 2011, there was a loss of about 1,000 feet of armor in the reach. Over 800 feet of that lost bank protection was flow deflectors; flanked barbs are visible in the middle of the channel downstream of the fairgrounds. With the avulsion of 2013, those flanked barbs are now sitting in the abandoned channel. Similar to reaches upstream, the river channel in Reach A4 has increased in size since 1950 by about 19 acres, and the channel expansion has been at the expense of riparian cover. Almost a quarter of the Channel Migration Zone (CMZ) has been restricted by physical features, and the restrictions are primarily due to bank armor that is protecting agricultural land.

Since 1950, over 7,500 feet of side channels in Reach A4 have been blocked by berms, which have caused a 25 percent drop in braiding parameter for the reach. Russian olive has colonized these historic channels. Like many other reaches the loss of active side channels in this reach has been accompanied by a lengthening of the main thread. Between 1950 and 2001, the main channel lengthened by about 1,000 feet through the 3.3 mile reach.

Land use in Reach A4 is predominantly agricultural, although there are several hundred acres of urban/exurban development associated with the town of Big Timber. Most of the agricultural land is non-irrigated; however there are hundreds of acres of flood, sprinkler, and pivot irrigation in the reach. Almost 150 acres of irrigated ground are within the 5-year floodplain in Reach A4, and most of that commonly flooded ground is south of the fairgrounds. This area also has most of the 160 acres of mapped wetlands in the reach.

There is one mapped dump site in Reach A4, which is on the high terrace edge at Big Timber. There is also one major petroleum product pipeline in the reach that runs parallel to the river on its north side. The pipeline is owned by ConocoPhillips, and passes under both Big Timber Creek and Otter Creek within 1,500 feet of the Yellowstone River.

Almost 200 acres of land in Reach A4 are within the mapped Channel Migration Zone. This includes 83 acres of flood, 42 acres of sprinkler, and 37 acres of pivot. A total of 21 acres of land in the CMZ has been developed to urban/exurban use.

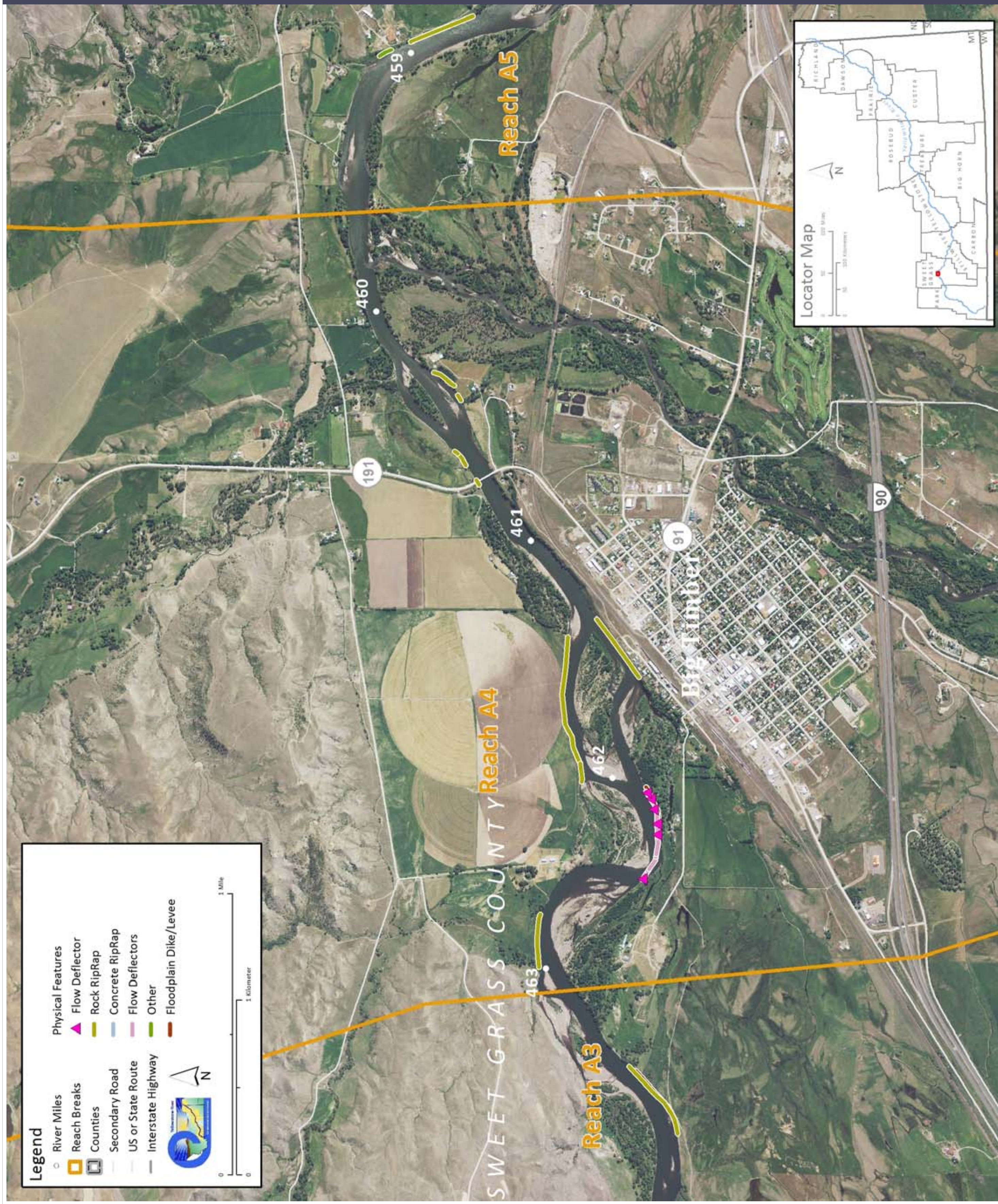
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 11,900 cfs to 11,500 cfs, a drop of about 3.4 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,880 cfs to 1,620 cfs with human development, a reduction of 14 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A4 include:
•Restriction of the Historic Migration Zone (HMZ) isolating side channels and reducing riparian turnover.
•Primary channel lengthening in association with loss of side channels.
•Rapid migration and channel realignment resulting in barb flanking and abandonment of rock in channel.
•Isolation of historic channels (over 7,500 feet) by berms.
•Russian olive colonization within isolated side channels.
•Riparian recruitment (cottonwood establishment) on islands created by channel migration.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A4 include:
•Removal of flanked armor at RM 462.3
•Side channel restoration/management (RM 461.2, RM 462)
•CMZ management due to encroachment (200 acres restricted)
•Russian olive removal (2.7 acres)
•Solid waste removal from dump on right bank at RM 461
•Pipeline management at Big Timber Creek and Otter Creek tributary crossings just north of Yellowstone River.

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	95.3	43.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	11,900	23,300	29,200	32,900	40,300	43,400	50,300	1,880	1,760
Regulated	11,500	22,900	28,800	32,500	40,000	43,200	50,100	1,620	1,680
% Change	-3.36%	-1.72%	-1.37%	-1.22%	-0.74%	-0.46%	-0.40%	-13.83%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	7/5/1948 - 7/13/51	B/W	1:23,600	6192500	9810
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	8/28/97 - 9/11/96	B/W		6192500	4840
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2005	NAIP	08/25/2005	color	1-meter pixels	6192500	2390
2005	NAIP	08/21/2005	color	1-meter pixels	6192500	2630
2007	Woolpert	10/15/2007 - 11/2/2007	Color		6192500	
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	NAIP	8/22/2011	Color	1-meter pixels	6192500	5480
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	
2013	NAIP	08/21/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	6,311	17.2%	6,143	16.8%	-168
	Flow Deflectors	449	1.2%	352	1.0%	-98
	Between Flow Deflectors	1,337	3.7%	581	1.6%	-757
	Feature Type Totals	**8,097**	**22.1%**	**7,075**	**19.3%**	**-1,022**
Floodplain Control						
	Transportation Encroachment	429	1.2%	429	1.2%	0
	Floodplain Dike/Levee	986	2.7%	986	2.7%	0
	Feature Type Totals	**1,415**	**3.9%**	**1,415**	**3.9%**	**0**
	Reach Totals	**9,512**	**26.0%**	**8,490**	**23.2%**	**-1,022**

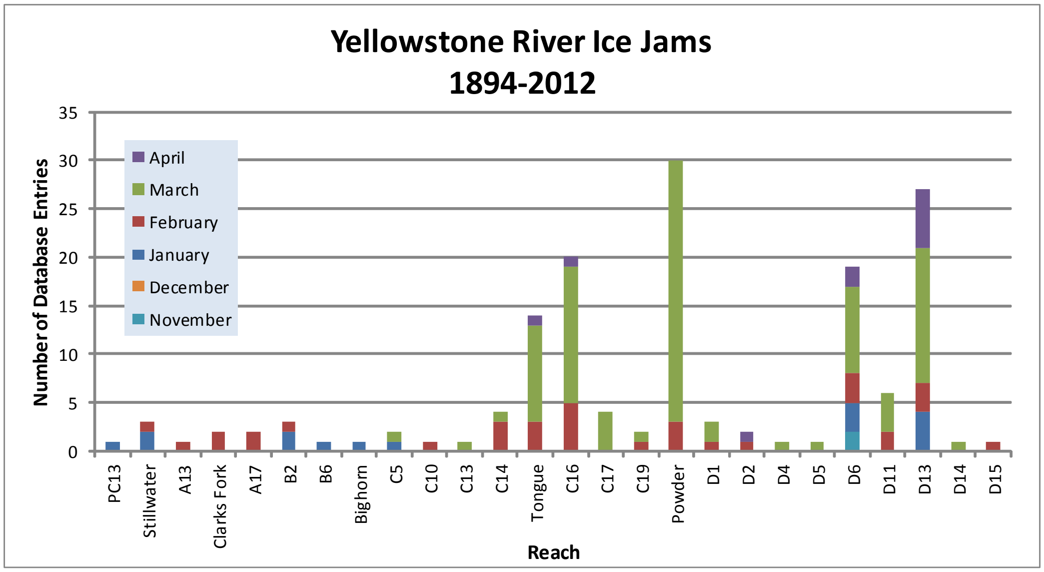
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	0	0	1,788	0	0	0	0	0
Rock RipRap	272	1,312	466	0	0	0	1,351	456
Totals	**272**	**1,312**	**2,253**	**0**	**0**	**0**	**1,351**	**456**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	17,375	16,020	1.92	1950 to 1976:	-8.19%
1976	17,028	13,019	1.76	1976 to 1995:	-17.10%
1995	18,251	8,448	1.46	1995 to 2001:	-2.22%
2001	18,302	7,877	1.43	1950 to 2001:	-25.58%
Change 1950 - 2001	**928**	**-8,143**	**-0.49**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	7,575

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	481		565	
Total Floodplain Area (Ac)	481		573	
Total Isolated (Ac)	**0**	**0.0%**	**9**	**2.7%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	95	41	14	**150**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
376	753	779	169	22%	12	12	100%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	19	2.4%
RipRap			
	Urban Residential	5	0.6%
	Non-Irrigated	52	6.6%
	Irrigated	50	6.4%
	Exurban Residential	20	2.6%
Dike/Levee			
	Non-Irrigated	37	4.6%
	Totals	**183**	**23.1%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
84.9	42.2	37.6	20.5	5.8

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	113	146	129	139	3.7%	4.8%	4.2%	4.6%
	Totals	**113**	**146**	**129**	**139**	**3.7%**	**4.8%**	**4.2%**	**4.6%**
Agricultural Land									
	Non-Irrigated	1,219	1,431	1,249	1,273	40.2%	47.2%	41.2%	42.0%
	Irrigated	1,162	858	900	882	38.3%	28.3%	29.7%	29.1%
	Totals	**2,381**	**2,289**	**2,148**	**2,155**	**78.5%**	**75.5%**	**70.9%**	**71.1%**
Channel									
	Channel	278	283	292	299	9.2%	9.3%	9.6%	9.9%
	Totals	**278**	**283**	**292**	**299**	**9.2%**	**9.3%**	**9.6%**	**9.9%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	28	19	0.0%	0.0%	0.9%	0.6%
	ExUrban Industrial	0	0	14	0	0.0%	0.0%	0.5%	0.0%
	ExUrban Commercial	22	22	36	44	0.7%	0.7%	1.2%	1.5%
	ExUrban Residential	0	0	42	42	0.0%	0.0%	1.4%	1.4%
	Totals	**22**	**23**	**120**	**105**	**0.7%**	**0.7%**	**3.9%**	**3.5%**
Transportation									
	Public Road	42	42	45	45	1.4%	1.4%	1.5%	1.5%
	Interstate	0	0	1	1	0.0%	0.0%	0.0%	0.0%
	Railroad	19	19	19	19	0.6%	0.6%	0.6%	0.6%
	Totals	**61**	**61**	**64**	**64**	**2.0%**	**2.0%**	**2.1%**	**2.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	61	60	78	78	2.0%	2.0%	2.6%	2.6%
	Urban Commercial	50	89	142	120	1.7%	2.9%	4.7%	4.0%
	Urban Undeveloped	65	63	53	66	2.2%	2.1%	1.8%	2.2%
	Urban Industrial	0	17	5	5	0.0%	0.6%	0.2%	0.2%
	Totals	**177**	**229**	**278**	**269**	**5.8%**	**7.6%**	**9.2%**	**8.9%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	208	195	0.0%	0.0%	9.7%	9.0%	0.0%	9.7%	-0.7%	9.0%
	Pivot	0	0	0	302	0.0%	0.0%	0.0%	14.0%	0.0%	0.0%	14.0%	14.0%
	Flood	1,162	858	692	385	48.8%	37.5%	32.2%	17.9%	-11.3%	-5.3%	-14.3%	-30.9%
	Totals	**1,162**	**858**	**900**	**882**	**48.8%**	**37.5%**	**41.9%**	**40.9%**	**-11.3%**	**4.4%**	**-1.0%**	**-7.9%**

Non-Irrigated

Multi-Use	1,027	1,167	1,123	1,128	43.1%	51.0%	52.3%	52.3%	7.9%	1.3%	0.1%	9.2%
Hay/Pasture	192	263	125	145	8.1%	11.5%	5.8%	6.7%	3.4%	-5.7%	0.9%	-1.3%
Totals	**1,219**	**1,431**	**1,249**	**1,273**	**51.2%**	**62.5%**	**58.1%**	**59.1%**	**11.3%**	**-4.4%**	**1.0%**	**7.9%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.5	0.1	1.7	1.9	1.5	1.5	0.7	3.9	5.6
Max	5.1	23.0	7.3	57.5	40.4	48.0	8.9	9.7	12.3
Average	2.4	2.7	3.6	18.4	11.3	14.7	5.6	6.4	8.4
Sum	22.0	46.6	21.7	275.5	181.0	205.3	22.6	19.1	25.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	78.5
Channel to Riparian (acres)	42.7
Riparian Encroachment (acres)	**-35.8**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	0.0
1950s Floodplain Mapped as 2011 Channel (Ac)	19.7
Total Recruitment (1950s to 2011)(Ac)	**19.7**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	3.7	140.0	20.5	0.0	**164.1**
Acres/Valley Mile	1.3	47.6	7.0	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	2.70	0.35%	1.27	1.16	1.36	0.92

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Sweet Grass	**Upstream River Mile**	459.7
Classification	UB: Unconfined braided	**Downstream River Mile**	456.4
General Location	Big Timber Creek	**Length**	3.30 mi (5.31 km)
General Comments	Low Qat1 terrace on right bank		

Narrative Summary

Reach A5 is approximately 3.3 miles long, and is located just below Big Timber near the Otter Creek Fishing Access Site starting just below the mouth of the Boulder River. Reach A5 is shows low migration rates and has a relatively narrow CMZ as a result. Similar to other reaches in Region A, the channel footprint has enlarged since 1950; in this reach the channel shows continual expansion from 1950 to 2001 of about 24 acres. This has been accompanied by a loss of 16 acres of riparian area in the main river corridor.

About 7 percent of the banks in Reach A5 are armored by rock riprap. Another 250 feet of bank is protected by tree revetments which are unusual on the Yellowstone River.

Land use in Reach A5 is predominantly agricultural, although there over 60 acres of urban/exurban development on the outskirts of Big Timber. Most of the agricultural land is non-irrigated, although there are almost 400 acres of ground under flood irrigation and another 150 acres under pivot. There are corrals associated with an Animal Holding Facility on the left bank of the river at RM 459.

Reach A5 has substantial irrigated land in the Channel Migration Zone. Land use mapping for 2011 conditions show 62 acres of flood, 2 acres of sprinkler, and 9 acres of pivot irrigated land within the CMZ boundary.

Reach A5 has seen almost a quarter (18 acres) of its riparian corridor converted to developed land uses since 1950. Most of that (17 acres) was conversion to irrigation.

Over 170 acres of wetland have been mapped in Reach A5. Most of the wetland area is on the eastern portion of the large alluvial fan formed at the mouth of the Boulder River, where there are open water wetlands and wet marsh areas.

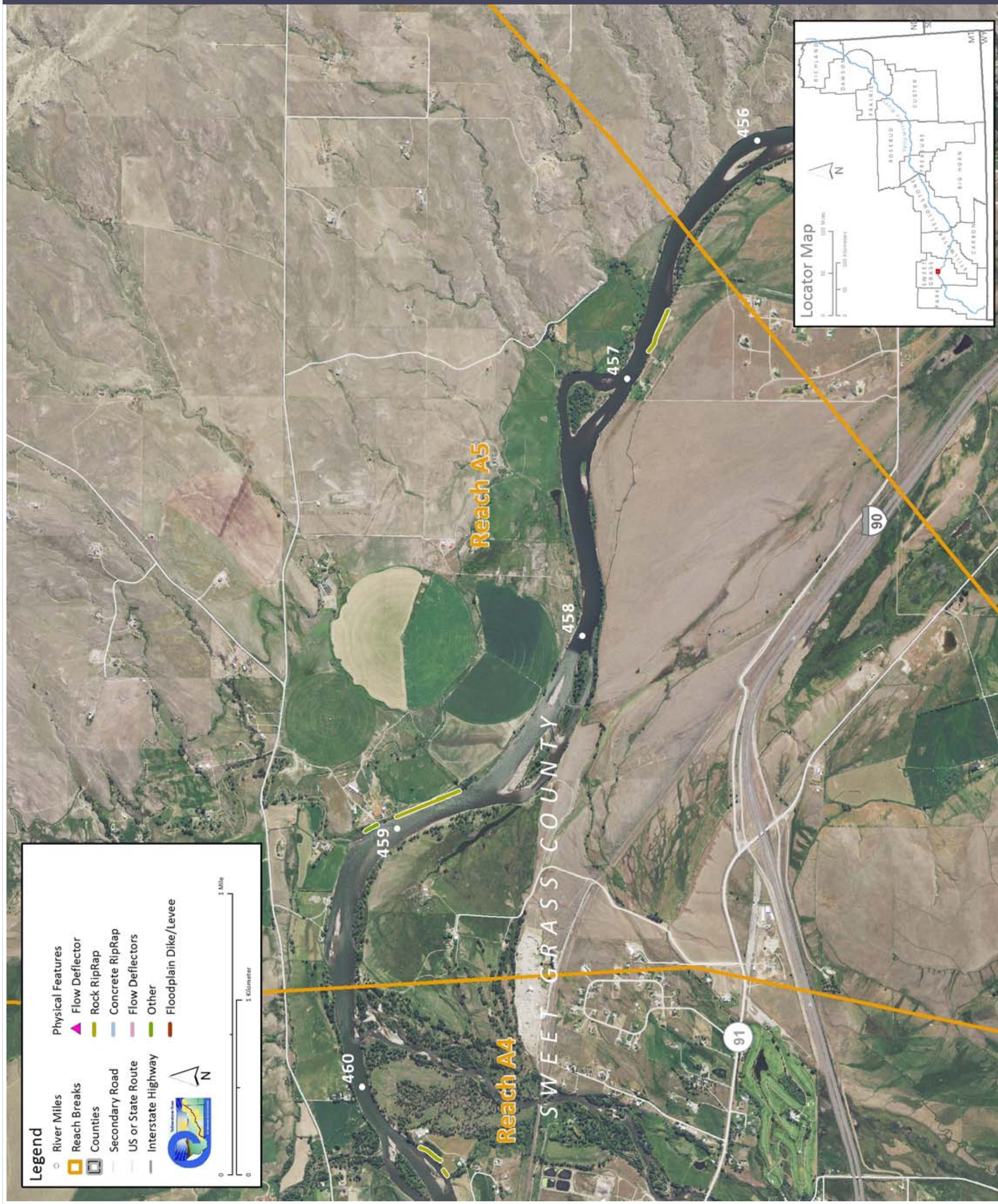
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 12,600 to 12,100 cfs, a drop of about 4 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,910 cfs to 1,630 cfs with human development, a reduction of 15 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A5 include:
•Riparian clearing in support of irrigation.
•Presence of corrals on the edge of the corridor at RM 459.
•Extensive wetland complex on low alluvial ground at the toe of a terrace.
•Encroachment of irrigated land into Channel Migration Zone.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A5 include:
•Nutrient management at corrals at RM 459
•Wetland management/restoration due to extent of emergent marsh (>170 acres)

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	92.0	46.9

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	12,600	24,500	30,800	34,600	42,400	45,500	52,700	1,910	1,760
Regulated	12,100	24,000	30,300	34,100	42,000	45,200	52,500	1,630	1,680
% Change	-3.97%	-2.04%	-1.62%	-1.45%	-0.94%	-0.66%	-0.38%	-14.66%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	13-Jul-51	B/W	1:28,400	6192500	9640
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	11-Sep-96	B/W		6192500	2560
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2005	NAIP	08/21/2005	color	1-meter pixels	6192500	2630
2005	NAIP	07/28/2005	color	1-meter pixels	6192500	3380
2007	Woolpert	10/15/2007 - 11/2/2007	Color		6192500	
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	NAIP	8/22/2011	Color	1-meter pixels	6192500	5480
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Tree Revetments	248	0.7%	248	0.7%	0
	Rock RipRap	1,266	3.7%	2,117	6.2%	851
	Feature Type Totals	**1,514**	**4.4%**	**2,365**	**6.9%**	**851**
	Reach Totals	**1,514**	**4.4%**	**2,365**	**6.9%**	**851**

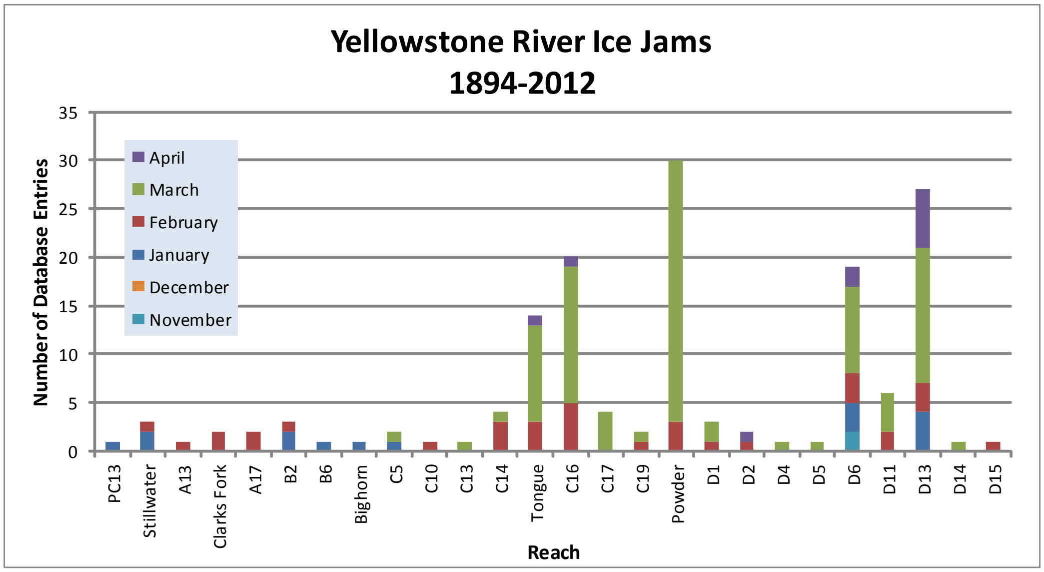
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	2,342	0	282	0	0	0	0	0
Tree Revetments	0	0	249	0	0	0	0	0
Totals	**2,342**	**0**	**531**	**0**	**0**	**0**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	17,866	9,054	1.51	1950 to 1976:	4.15%
1976	16,871	9,604	1.57	1976 to 1995:	1.96%
1995	17,021	10,213	1.60	1995 to 2001:	-5.93%
2001	17,021	8,598	1.51	1950 to 2001:	-0.11%
Change 1950 - 2001	**-845**	**-456**	**0.00**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	96		214	
Total Floodplain Area (Ac)	96		215	
Total Isolated (Ac)	**0**	**0.0%**	**1**	**-31.1%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	1	0	0	**1**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
113	225	428	11	3%	0	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Other Infrastructure	10	2.3%
	Irrigated	6	1.4%
	Totals	**16**	**3.7%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
62.9	1.9	9.2	6.7	0.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	18	34	62	63	1.0%	1.9%	3.4%	3.5%
	Totals	**18**	**34**	**62**	**63**	**1.0%**	**1.9%**	**3.4%**	**3.5%**
Agricultural Land									
	Non-Irrigated	847	798	936	893	46.6%	43.9%	51.5%	49.1%
	Irrigated	734	746	543	554	40.4%	41.1%	29.9%	30.5%
	Totals	**1,581**	**1,544**	**1,479**	**1,447**	**87.0%**	**85.0%**	**81.4%**	**79.7%**
Channel									
	Channel	210	219	236	235	11.5%	12.0%	13.0%	13.0%
	Totals	**210**	**219**	**236**	**235**	**11.5%**	**12.0%**	**13.0%**	**13.0%**
ExUrban									
	ExUrban Other	0	0	5	5	0.0%	0.0%	0.3%	0.3%
	ExUrban Undeveloped	0	0	3	7	0.0%	0.0%	0.2%	0.4%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	1	13	18	18	0.0%	0.7%	1.0%	1.0%
	ExUrban Residential	0	0	6	33	0.0%	0.0%	0.3%	1.8%
	Totals	**1**	**13**	**32**	**64**	**0.0%**	**0.7%**	**1.8%**	**3.5%**
Transportation									
	Public Road	4	4	4	4	0.2%	0.2%	0.2%	0.2%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	3	3	3	3	0.2%	0.2%	0.2%	0.2%
	Totals	**7**	**7**	**7**	**7**	**0.4%**	**0.4%**	**0.4%**	**0.4%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	8	0.0%	0.0%	0.0%	0.6%	0.0%	0.0%	0.6%	0.6%
	Pivot	0	0	78	154	0.0%	0.0%	5.2%	10.7%	0.0%	5.2%	5.4%	10.7%
	Flood	734	746	465	392	46.4%	48.3%	31.5%	27.1%	1.9%	-16.8%	-4.4%	-19.4%
	Totals	**734**	**746**	**543**	**554**	**46.4%**	**48.3%**	**36.7%**	**38.3%**	**1.9%**	**-11.6%**	**1.6%**	**-8.1%**

Non-Irrigated												
Multi-Use	690	772	885	852	43.6%	50.0%	59.8%	58.9%	6.4%	9.8%	-0.9%	15.3%
Hay/Pasture	157	26	51	40	9.9%	1.7%	3.4%	2.8%	-8.3%	1.8%	-0.6%	-7.1%
Totals	**847**	**798**	**936**	**893**	**53.6%**	**51.7%**	**63.3%**	**61.7%**	**-1.9%**	**11.6%**	**-1.6%**	**8.1%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.3	0.1	0.1	1.7	1.4	0.7	3.8	1.3	6.9
Max	1.8	2.3	1.5	8.4	10.6	17.1	11.9	7.1	6.9
Average	1.1	0.8	0.8	4.3	4.4	5.1	7.5	4.8	6.9
Sum	2.2	6.6	3.3	55.9	61.1	51.3	29.8	14.5	6.9

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	24.2
Channel to Riparian (acres)	8.3
Riparian Encroachment (acres)	**-15.9**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	6.3	157.3	9.5	0.0	**173.2**
Acres/Valley Mile	2.1	52.8	3.2	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.21	0.08%	0.28	0.08	0.01	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

Yellowstone River Reach Narratives — Reach A6

County	Sweet Grass	**Upstream River Mile**	456.4
Classification	PCS: Partially confined straight	**Downstream River Mile**	453.3
General Location	Below Big Timber	**Length**	3.10 mi (4.99 km)
General Comments	Channel closely follows left valley wall		

Narrative Summary

Reach A6 is approximately 3.1 miles long, and is located below Big Timber. The reach is classified as Partially Confined Straight (PCS), which indicates some valley wall influences on river form and minimal meandering. Within this reach, the river consistently follows the northern bluff line of the river valley which is comprised of Cretaceous-age Hell Creek Formation sandstones and mudstones. The other side of the river consists of low floodplain and terrace deposits. Because of the valley wall confinement, migration rates are low in the reach and the Channel Migration Zone (CMZ) is narrow.

Similar to other reaches in Region A, the overall footprint of the river channel has increased in size since 1950. In 1950, the channel footprint was 161 acres but by 2001 it had expanded to 202 acres.

About 7 percent of the banks in Reach A6 are armored, and most of that bank protection is flow deflectors (2,165 feet). There is another 650 feet of rock riprap, all of which was constructed between 2001 and 2011.

One side channel in Reach A6 was blocked prior to 1950. It is about 2,700 feet long and is blocked by a dike as well as flow deflectors along the bank. The side channel currently hosts riverine and emergent wetland areas.

Land use in Reach A6 is predominantly agricultural, although there almost 200 acres of exurban development on the low terraces between the river and I-90. Most of the agricultural land is non-irrigated, although there are 760 acres of ground under flood irrigation and another 64 acres under pivot. A total of 35 acres of flood irrigated land are in the Channel Migration Zone.

Reach A6 has seen 28 percent (18 acres) of its riparian corridor converted to developed land uses since 1950. Most of that (17 acres) was conversion to irrigation.

This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

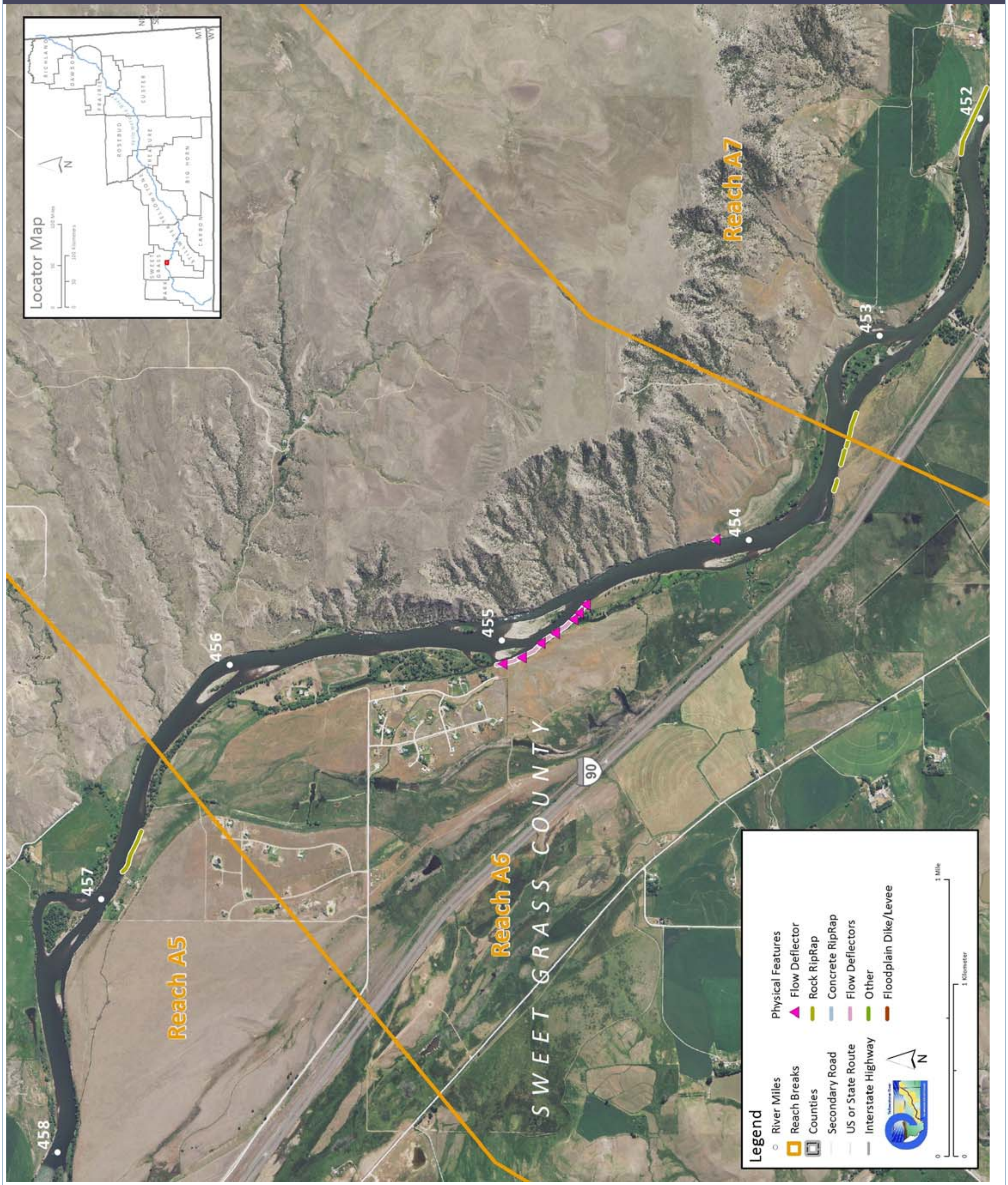
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 12,600 to 12,100 cfs, a drop of about 4 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,910 cfs to 1,630 cfs with human development, a reduction of 15 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

The reduction in flows is evident by the contraction of the 5-year floodplain area in Reach A6 by 4.8 acres, or 30 percent.

CEA-Related observations in Reach A6 include:
•Riparian clearing in support of irrigation.
•Side Channel Blockage
•Contraction of 5-year floodplain due to flow alterations.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A6 include:
•Side channel restoration at RM 454.5

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	88.9	50.2

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	12,600	24,500	30,800	34,600	42,400	45,500	52,700	1,910	1,760
Regulated	12,100	24,000	30,300	34,100	42,000	45,200	52,500	1,630	1,680
% Change	-3.97%	-2.04%	-1.62%	-1.45%	-0.94%	-0.66%	-0.38%	-14.66%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	13-Jul-51	B/W	1:28,400	6192500	9640
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	11-Sep-96	B/W		6192500	2560
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2005	NAIP	07/28/2005	color	1-meter pixels	6192500	3380
2007	Woolpert	10/15/2007 - 11/2/2007	Color		6192500	
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	NAIP	8/22/2011	Color	1-meter pixels	6192500	5480
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	0	0.0%	648	2.1%	648
	Flow Deflectors	580	1.9%	633	2.0%	52
	Between Flow Deflectors	1,544	4.9%	1,533	4.9%	-11
	Feature Type Totals	**2,124**	**6.8%**	**2,814**	**9.0%**	**690**
Other In Channel						
	Bedrock Outcrop	157	0.5%	157	0.5%	0
	Feature Type Totals	**157**	**0.5%**	**157**	**0.5%**	**0**
Floodplain Control						
	Transportation Encroachment	7,844	25.0%	7,844	25.0%	0
	Feature Type Totals	**7,844**	**25.0%**	**7,844**	**25.0%**	**0**
	Reach Totals	**10,125**	**32.3%**	**10,815**	**34.5%**	**690**

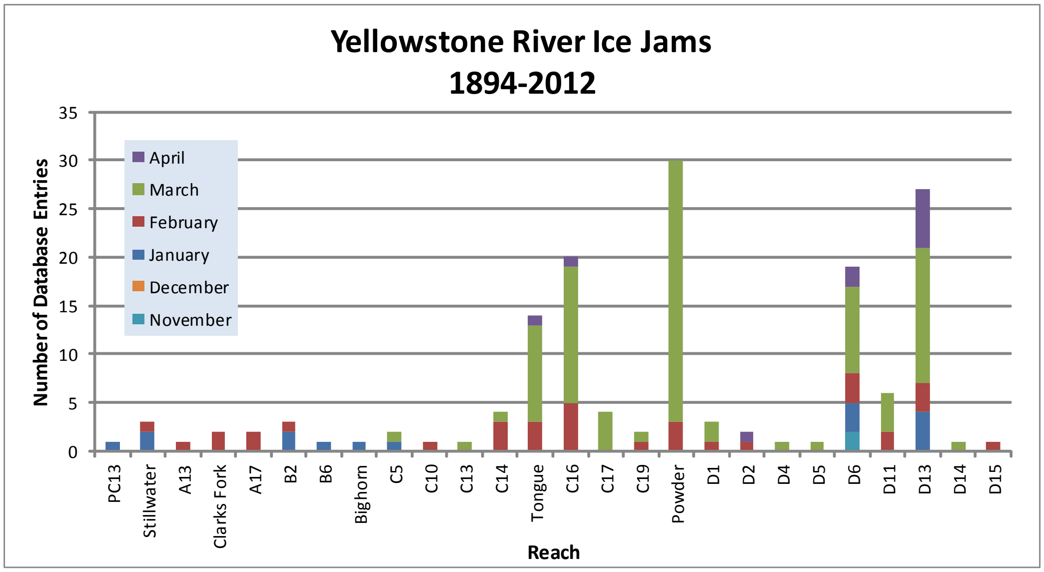
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	1,968	0	0	0	0	0	0	154
Totals	**1,968**	**0**	**0**	**0**	**0**	**0**	**0**	**154**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	15,359	1,749	1.11	1950 to 1976:	-10.23%
1976	15,307		1.00	1976 to 1995:	9.11%
1995	15,523	1,414	1.09	1995 to 2001:	-2.30%
2001	15,675	1,034	1.07	1950 to 2001:	-4.30%
Change 1950 - 2001	**316**	**-715**	**-0.05**		

Length of Side Channels Blocked

Pre-1950s (ft)	2,691
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	103		213	
Total Floodplain Area (Ac)	103		218	
Total Isolated (Ac)	**0**	**0.0%**	**5**	**30.5%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	1	0	0	**1**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
146	292	304	14	5%	30	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Irrigated	6	1.8%
Flow Deflectors			
	Irrigated	14	4.2%
	Totals	**20**	**6.0%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
35.4	0.0	0.0	3.5	0.5

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	17	22	22	6	0.8%	1.1%	1.1%	0.3%
	Totals	**17**	**22**	**22**	**6**	**0.8%**	**1.1%**	**1.1%**	**0.3%**
Agricultural Land									
	Non-Irrigated	885	947	805	714	43.8%	46.8%	39.8%	35.3%
	Irrigated	936	870	834	825	46.3%	43.0%	41.2%	40.8%
	Totals	**1,822**	**1,817**	**1,639**	**1,539**	**90.0%**	**89.8%**	**81.0%**	**76.0%**
Channel									
	Channel	166	165	181	202	8.2%	8.1%	8.9%	10.0%
	Totals	**166**	**165**	**181**	**202**	**8.2%**	**8.1%**	**8.9%**	**10.0%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	37	0.0%	0.0%	0.0%	1.8%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	104	162	0.0%	0.0%	5.1%	8.0%
	Totals	**0**	**0**	**104**	**199**	**0.0%**	**0.0%**	**5.1%**	**9.8%**
Transportation									
	Public Road	7	7	7	7	0.3%	0.3%	0.3%	0.3%
	Interstate	0	0	58	58	0.0%	0.0%	2.9%	2.9%
	Railroad	13	13	13	13	0.6%	0.6%	0.6%	0.6%
	Totals	**19**	**19**	**77**	**77**	**0.9%**	**0.9%**	**3.8%**	**3.8%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	64	0.0%	0.0%	0.0%	4.2%	0.0%	0.0%	4.2%	4.2%
	Flood	936	870	834	761	51.4%	47.9%	50.9%	49.5%	-3.5%	3.0%	-1.4%	-1.9%
	Totals	**936**	**870**	**834**	**825**	**51.4%**	**47.9%**	**50.9%**	**53.6%**	**-3.5%**	**3.0%**	**2.7%**	**2.2%**

Non-Irrigated												
Multi-Use	855	738	791	681	46.9%	40.6%	48.3%	44.3%	-6.3%	7.7%	-4.0%	-2.7%
Hay/Pasture	30	210	13	32	1.7%	11.5%	0.8%	2.1%	9.9%	-10.7%	1.3%	0.4%
Totals	**885**	**947**	**805**	**714**	**48.6%**	**52.1%**	**49.1%**	**46.4%**	**3.5%**	**-3.0%**	**-2.7%**	**-2.2%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.7	0.1	2.9	0.6	0.3	0.3	20.4	17.1	2.2
Max	17.0	5.4	2.9	18.0	13.3	10.8	53.8	25.3	23.9
Average	5.2	1.2	2.9	5.2	3.7	3.8	37.1	21.2	10.6
Sum	46.7	8.2	2.9	26.0	29.6	15.0	74.2	42.4	42.3

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	10.7
Channel to Riparian (acres)	4.2
Riparian Encroachment (acres)	**-6.5**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	14.3	23.3	1.1	0.0	**38.6**
Acres/Valley Mile	5.1	8.3	0.4	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.11	0.01%	0.01	0.00	0.01	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Sweet Grass	**Upstream River Mile**	453.3
Classification	PCB: Partially confined braided	**Downstream River Mile**	443.6
General Location	Greycliff	**Length**	9.70 mi (15.61 km)
General Comments	Greycliff: Narrow valley bottom with alluvial fan margins		

Narrative Summary

Reach A7 is approximately 9.7 miles long, and is at Greycliff. The reach is classified as Partially Confined Braided (PCB), which indicates some valley wall influences on river form and relatively extensive gravel bars and low flow channel complexity. Within this reach, the river intermittently follows the northern bluff line of the river valley which is comprised of Cretaceous-age Hell Creek Formation sandstones and mudstones. The other side of the river valley consists of low floodplain and terrace deposits. In several places, such as at Greycliff Bridge, the terrace toe is sandstone. Several tributaries enter the river in this reach, including Sweet Grass Creek and Deer Creek.

Similar to other reaches in Region A, the overall footprint of the river channel has increased in size since 1950. In 1950, the channel footprint was 613 acres but by 2001 it had expanded to 723 acres.

As of 2011, about 12 percent of the banks in Reach A7 were armored, and most of that bank protection is rock riprap (11,254 feet). There are also 1,500 feet of flow deflectors in the reach. Between 2001 and 2011, about 2,400 feet of riprap and 230 feet of flow deflectors were constructed. There are also minor amounts of gabions and steel retaining wall in the reach.

Reach A7 has experienced the loss of thousands of feet of side channels both pre- and post- 1950. Prior the collection of the 1950s imagery, a channel that was almost a mile long was blocked in multiple places. The land that this blocked side channel is about ½ mile downstream of the Greycliff Bridge on the right bank and is part of the Pelican Fishing Access Site. Currently, only the downstream portion of this channel has good definition; the upper end has largely decayed. Since 1950, side channels have been blocked at RM 445 and RM 452. Both of these side channels were relatively small features that flowed on the south side of the river corridor. In total, 4,600 feet of channel were blocked post-1950. Since 1950 there has been a net loss of about 9,000 feet of side channel in the reach, indicating some passive loss as well as loss due to blockages.

In contrast to the general trend on the river, floodplain turnover rates in Reach A7 have increased since 1976. From 1950-1976 the average floodplain turnover rate in this reach was 3.4 acres per year, and from 1976-2001, that rate had increased to 5.5 acres per year.

Land use in Reach A7 is predominantly agricultural, although there almost 140 acres of exurban development on the low terraces between the river and I-90. Transportation infrastructure also comprises almost 300 acres of the mapping footprint. Most of the agricultural land is non-irrigated, although there are 1,500 acres of ground under flood irrigation, 225 acres under sprinkler and another 914 acres under pivot. A total of 267 acres of developed land are in the Channel Migration Zone. Most of that is in flood irrigation (196 acres), but 51 acres are in pivot. At RM 450, pivots extend to the active streambank on both sides of the river. About 10 percent of the CMZ is restricted by physical features.

Reach A7 has seen 5 percent (33 acres) of its riparian corridor converted to developed land uses since 1950. Most of that (23 acres) was conversion to irrigation. Currently, there are about 26 acres of land under pivot irrigation within the mapped 5-year floodplain.

Reach A7was sampled as part of the avian study. The average species richness in Reach A7 was 9.9, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. One bird Species of Concern (SOC), the Bobolink, was identified in the reach. Three bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were also found, including the Chimney Swift, Dickscissel, and Ovenbird.

On area in Reach A7 that has become persistently problematic is the Greycliff Bridge at RM 448.5. Bank migration upstream of the bridge has approached 1,000 feet of lateral movement since 1950. Bank armor has been flanked and now sits In the middle of the river. The county road that lies in the CMZ has been threatened; it was treated with buried revetment that has become exposed in recent years. Efforts are ongoing to develop an optimal strategy to funnel the river meanderbelt through the bridge without disrupting sediment transport patterns and causing accelerated erosion.

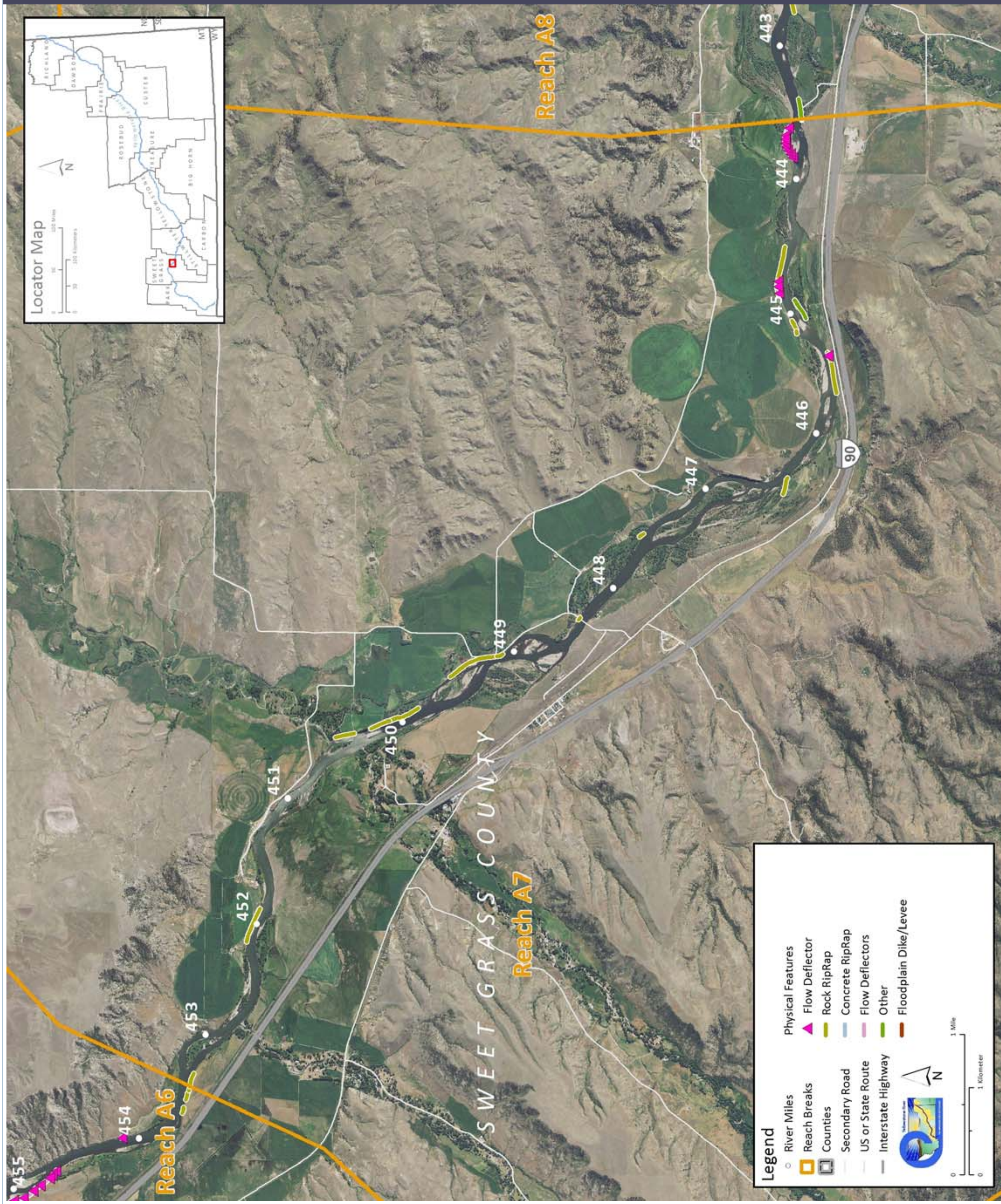
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 13,200 cfs to 12,700 cfs, a drop of about 4 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,000 cfs to 1,670 cfs with human development, a reduction of 17 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

The reduction in flows is evident by the contraction of the 5-year floodplain area in Reach A7 by 62 acres, or 25 percent.

CEA-Related observations in Reach A7 include:
•Flanking of armor and accelerated erosion behind.
•Side Channel Blockage
•Contraction of 5-year floodplain due to flow alterations.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A7 include:
•Side channel restoration RM 452, RM 447.9, RM 445
•Bank armor removal upstream of Greycliff Bridge
•CMZ management due to encroachment of pivots

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	79.2	53.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	13,200	25,600	32,100	36,000	44,100	47,400	54,800	2,000	1,760
Regulated	12,700	25,100	31,600	35,500	43,700	47,100	54,600	1,670	1,680
% Change	-3.79%	-1.95%	-1.56%	-1.39%	-0.91%	-0.63%	-0.36%	-16.50%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	6/15/1951 - 7/12/51	B/W	1:28,400	6192500	13700
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	9/11/96 - 8/28/97	B/W		6192500	2560
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2005	NAIP	07/28/2005	color	1-meter pixels	6192500	3380
2005	NAIP	07/27/2005	color	1-meter pixels	6192500	3540
2007	Woolpert	10/15/2007 - 11/2/2007	Color		6192500	
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	NAIP	8/22/2011	Color	1-meter pixels	6192500	5480
2011	NAIP	7/24/2011	Color	1-meter pixels	6192500	13100
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Steel Retaining Wall	33	0.0%	33	0.0%	0
	Rock RipRap	8,917	8.5%	11,255	10.8%	2,338
	Gabions	797	0.8%	797	0.8%	0
	Flow Deflectors	305	0.3%	531	0.5%	226
	Between Flow Deflectors	977	0.9%	977	0.9%	0
	Feature Type Totals	**11,028**	**10.6%**	**13,592**	**13.0%**	**2,564**
Other In Channel						
	Bedrock Outcrop	74	0.1%	74	0.1%	0
	Feature Type Totals	**74**	**0.1%**	**74**	**0.1%**	**0**
Floodplain Control						
	Transportation Encroachment	10,046	9.6%	10,046	9.6%	0
	Feature Type Totals	**10,046**	**9.6%**	**10,046**	**9.6%**	**0**
	Reach Totals	**21,148**	**20.2%**	**23,712**	**22.7%**	**2,564**

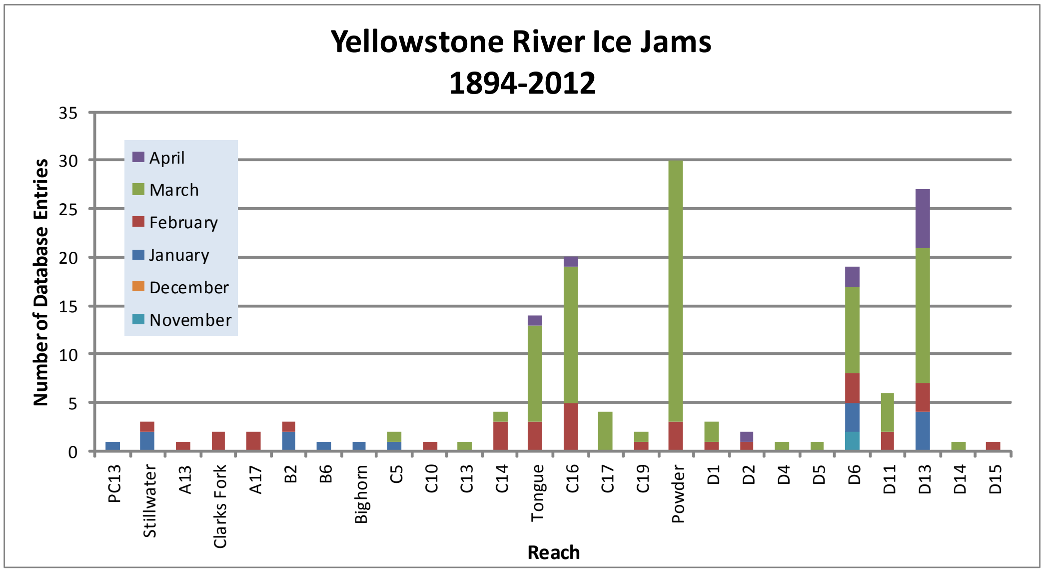
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Gabions	0	0	797	0	0	0	0	0
Rock RipRap	4,943	3,241	656	656	0	1,187	0	0
Totals	**4,943**	**3,241**	**1,453**	**656**	**0**	**1,187**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	51,418	30,696	1.60
1976	51,762	42,983	1.83
1995	52,381	25,182	1.48
2001	52,254	21,606	1.41
Change 1950 - 2001	**836**	**-9,090**	**-0.18**

	% Change in Braiding
1950 to 1976:	14.62%
1976 to 1995:	-19.10%
1995 to 2001:	-4.54%
1950 to 2001:	-11.49%

Length of Side Channels Blocked

Pre-1950s (ft)	4,756
Post-1950s (ft)	4,610

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	13	1.6%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	780		911	
Total Floodplain Area (Ac)	793		973	
Total Isolated (Ac)	**13**	**1.6%**	**62**	**24.8%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	5	0	25	**31**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
240	481	1,597	147	9%	68	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	7	0.4%
RipRap/Flow Deflectors			
	Irrigated	20	1.2%
RipRap			
	Railroad	16	1.0%
	Non-Irrigated	54	3.2%
	Irrigated	37	2.2%
Other			
	Public Road	3	0.2%
	Other Infrastructure	11	0.6%
Flow Deflectors			
	Irrigated	16	1.0%
	Totals	**164**	**9.9%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
195.9	0.0	50.6	5.1	15.4

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	1976	2001	2011	% of Reach Area 1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	1	7	0.0%	0.0%	0.0%	0.1%
	Other Infrastructure	78	107	161	161	1.2%	1.6%	2.4%	2.4%
	Totals	**78**	**107**	**162**	**168**	**1.2%**	**1.6%**	**2.5%**	**2.6%**
Agricultural Land									
	Non-Irrigated	3,626	3,238	2,560	2,551	55.2%	49.3%	38.9%	38.8%
	Irrigated	2,027	2,203	2,663	2,604	30.8%	33.5%	40.5%	39.6%
	Totals	**5,653**	**5,441**	**5,224**	**5,155**	**86.0%**	**82.8%**	**79.5%**	**78.4%**
Channel									
	Channel	716	760	763	817	10.9%	11.6%	11.6%	12.4%
	Totals	**716**	**760**	**763**	**817**	**10.9%**	**11.6%**	**11.6%**	**12.4%**
ExUrban									
	ExUrban Other	0	5	9	13	0.0%	0.1%	0.1%	0.2%
	ExUrban Undeveloped	0	0	6	0	0.0%	0.0%	0.1%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	8	12	0.0%	0.0%	0.1%	0.2%
	ExUrban Residential	17	20	107	113	0.3%	0.3%	1.6%	1.7%
	Totals	**17**	**25**	**130**	**138**	**0.3%**	**0.4%**	**2.0%**	**2.1%**
Transportation									
	Public Road	64	83	87	87	1.0%	1.3%	1.3%	1.3%
	Interstate	0	112	162	162	0.0%	1.7%	2.5%	2.5%
	Railroad	46	46	46	46	0.7%	0.7%	0.7%	0.7%
	Totals	**110**	**241**	**295**	**296**	**1.7%**	**3.7%**	**4.5%**	**4.5%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	1976	2001	2011	% of Reach Area 1950	1976	2001	2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	250	224	0.0%	0.0%	4.8%	4.4%	0.0%	4.8%	-0.4%	4.4%
	Pivot	0	0	941	914	0.0%	0.0%	18.0%	17.7%	0.0%	18.0%	-0.3%	17.7%
	Flood	2,027	2,203	1,473	1,466	35.9%	40.5%	28.2%	28.4%	4.6%	-12.3%	0.2%	-7.4%
	Totals	**2,027**	**2,203**	**2,663**	**2,604**	**35.9%**	**40.5%**	**51.0%**	**50.5%**	**4.6%**	**10.5%**	**-0.5%**	**14.7%**

Non-Irrigated													
	Multi-Use	2,832	2,620	2,113	2,085	50.1%	48.2%	40.5%	40.5%	-1.9%	-7.7%	0.0%	-9.6%
	Hay/Pasture	794	618	447	465	14.0%	11.4%	8.6%	9.0%	-2.7%	-2.8%	0.5%	-5.0%
	Totals	**3,626**	**3,238**	**2,560**	**2,551**	**64.1%**	**59.5%**	**49.0%**	**49.5%**	**-4.6%**	**-10.5%**	**0.5%**	**-14.7%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.5	0.2	0.3	0.1	0.1	0.1	1.8	2.7	0.1
Max	36.8	28.6	15.4	87.2	87.7	80.3	38.2	48.3	40.8
Average	6.8	5.0	4.8	18.2	8.2	14.2	14.2	21.0	11.7
Sum	136.8	75.3	100.0	417.7	391.6	382.4	99.3	105.0	93.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	112.5
Channel to Riparian (acres)	108.7
Riparian Encroachment (acres)	**-3.8**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	0.0
1950s Floodplain Mapped as 2011 Channel (Ac)	5.4
Total Recruitment (1950s to 2011)(Ac)	**5.4**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	14.1	56.6	42.5	0.0	**113.2**
Acres/Valley Mile	1.6	6.2	4.7	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.51	0.05%	0.77	0.04	0.19	0.02

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern Potential Species of Concern

Reach	Region	
✓	✓	American Robin
✓	✓	American Crow
✓	✓	American Goldfinch
		American Kestrel
✓	✓	American Redstart
		Bald Eagle
		Baltimore Oriole
✓	✓	Barn Swallow
		Belted Kingfisher
		Black-billed Cuckoo
	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
	✓	Black-and-white Warbler
✓	✓	Black-headed Grosbeak
	✓	Blue Jay
✓	✓	Bobolink
	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
		Brown Creeper
	✓	Brown Thrasher
✓	✓	Bullock's Oriole
		Canada Goose
✓	✓	Cedar Waxwing
✓	✓	Chimney Swift
✓	✓	Chipping Sparrow
	✓	Clay-collared Sparrow
✓	✓	Cliff Swallow
✓	✓	Common Grackle
		Common Merganser
		Common Nighthawk
		Common Raven
✓	✓	Common Yellowthroat
		Cooper's Hawk
✓	✓	Dickcissel
✓	✓	Downy Woodpecker
		Eastern Bluebird
✓	✓	Eastern Kingbird
		Eurasian Collared-dove
✓	✓	European Starling
	✓	Field Sparrow
		Franklin's Gull
		Grasshopper Sparrow
✓	✓	Gray Catbird
		Great Blue Heron
		Great Horned Owl
✓	✓	Hairy Woodpecker
		House Finch
✓	✓	House Wren
		Killdeer
		Lark Bunting
✓	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
		Mallard
✓	✓	Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
		Orchard Oriole
		Osprey
✓	✓	Ovenbird
		Plumbeous Vireo
		Red-headed Woodpecker
	✓	Red-naped Sapsucker
		Red Crossbill
		Ring-necked Pheasant
		Red-tailed hawk
		Rock Dove
✓	✓	Red-winged Blackbird
	✓	Red-eyed Vireo
		Red-breasted Grosbeak
		Say's Phoebe
✓	✓	Savannah Sparrow
✓	✓	Song Sparrow
		Spotted Sandpiper
✓	✓	Spotted Towhee
		Sharp-shinned Hawk
✓	✓	Swainson's Thrush
		Sandhill Crane
✓	✓	Tree Swallow
		Turkey Vulture
		Upland Sandpiper
	✓	Vesper Sparrow
✓	✓	Violet-green Swallow
✓	✓	Warbling Vireo
	✓	Western Kingbird
✓	✓	Western Meadowlark
✓	✓	Western Wood-pewee
	✓	White-breasted Nuthatch
	✓	White-throated Swift
		Wild Turkey
		Wood Duck
		Yellow-bellied Sapsucker
		Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
✓	✓	Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included. There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Sweet Grass	**Upstream River Mile**	443.6
Classification	PCB: Partially confined braided	**Downstream River Mile**	438.5
General Location	Bridger Creek	**Length**	5.10 mi (8.21 km)
General Comments	Floodplain isolation behind interstate and R/R		

Narrative Summary

Reach A8 is 5.1 miles long, and is at Bridger Creek. The reach is classified as Partially Confined Braided (PCB), which indicates some valley wall influences on river form and relatively extensive gravel bars and low flow channel complexity. Within this reach, the river intermittently follows the northern bluff line of the river valley which is comprised of Cretaceous-age Hell Creek Formation sandstones and mudstones. The other side of the river valley consists of low floodplain and terrace deposits. The Bratten fishing access site is located in the lower end of the reach.

Similar to other reaches in Region A, the overall footprint of the river channel has increased in size since 1950. In 1950, the channel footprint was 436 acres but by 2001 it had expanded to 482 acres.

As of 2011, about 10 percent of the banks in Reach A8 were armored by almost 4,000 feet of rock riprap and 1,400 feet of flow deflectors. There is also a ~760 foot long retaining wall on the right bank at the very upstream most end of the reach that protects several structures. At Rm 441.1, rock riprap on both sides of the river has constricted the channel corridor to essentially the width of the active channel, which is about 550 feet. Physical features also occupy the floodplain; over three miles of transportation encroachment and 1,800 feet of floodplain dikes have been mapped in the reach. Transportation infrastructure and agriculture-related dikes have isolated 25 percent of the historic 100-year floodplain in the reach.

Reach A8 has experienced the loss of almost a mile of side channel since the 1950s due to dike construction. All of the side channel loss is from one project at the mouth of Bridger Creek, where the lower portion of the creek was channelized downstream of the I-90 Bridge. This channelization included re-routing the creek through a channelized section to an active side channel of the Yellowstone River. The channelization included construction of a dike that guides Bridger Creek into the side channel, and blocks the side channel at the intersection, essentially turning the lower portion of the side channel into lowermost Bridger Creek. The channelization of lower Bridger Creek occurred between 1950 and 1976.

Even though Reach A8 has experienced some side channel loss, it still supports extensive side channel length. As of 2001 there were 6.6 miles of active side channel in the 5.1 mile long reach.

Land use in Reach A8 is predominantly agricultural, although there almost 230 acres of transportation-related development in the mapping footprint. Most of the agricultural land is non-irrigated, although there are 900 acres of ground under flood irrigation and 56 acres under pivot. A total of 236 acres of developed land are in the Channel Migration Zone. Most of that is in flood irrigation (211 acres), but 8 acres are in pivot and 4 are in exurban development. About 16 percent of the CMZ is restricted by physical features.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 13,700 cfs to 13,000 cfs, a drop of about 5 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,020 cfs to 1,670 cfs with human development, a reduction of 17 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

The reduction in flows is evident by the contraction of the 5-year floodplain area in Reach A8 by 24 acres, or 11 percent.

CEA-Related observations in Reach A8 include:
•Side channel loss as part of tributary channelization
•Isolation of 25 percent of historic 100-year floodplain primary due to transportation infrastructure
•Contraction of 5-year floodplain due to flow alterations.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A8 include:
•Side channel restoration at RM 442
•Floodplain restoration/reconnection on south side of interstate at RM 439.5
•CMZ management due to extent of CMZ restriction (16 percent)

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	74.1	63.0

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	13,700	26,600	33,200	37,300	45,600	49,000	56,700	2,020	1,760
Regulated	13,000	25,800	32,400	36,600	45,000	48,500	56,400	1,670	1,680
% Change	-5.11%	-3.01%	-2.41%	-1.88%	-1.32%	-1.02%	-0.53%	-17.33%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	7/12/1951 - 6/15/51	B/W	1:28,400	6192500	13700
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	9/26/97 - 9/11/96	B/W		6192500	2560
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2005	NAIP	07/27/2005	color	1-meter pixels	6192500	3540
2007	Woolpert	10/15/2007 - 11/2/2007	Color	NA	6192500	
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	NAIP	7/24/2011	Color	1-meter pixels	6192500	13100
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Steel Retaining Wall	758	1.4%	758	1.4%	0
	Rock RipRap	3,697	6.9%	3,970	7.4%	274
	Flow Deflectors	451	0.8%	431	0.8%	-21
	Between Flow Deflectors	1,098	2.1%	985	1.8%	-113
	Feature Type Totals	**6,004**	**11.2%**	**6,144**	**11.5%**	**140**
Floodplain Control						
	Transportation Encroachment	15,631	29.2%	15,631	29.2%	0
	Floodplain Dike/Levee	1,853	3.5%	1,853	3.5%	0
	Feature Type Totals	**17,484**	**32.7%**	**17,484**	**32.7%**	**0**
	Reach Totals	**23,489**	**43.9%**	**23,628**	**44.1%**	**140**

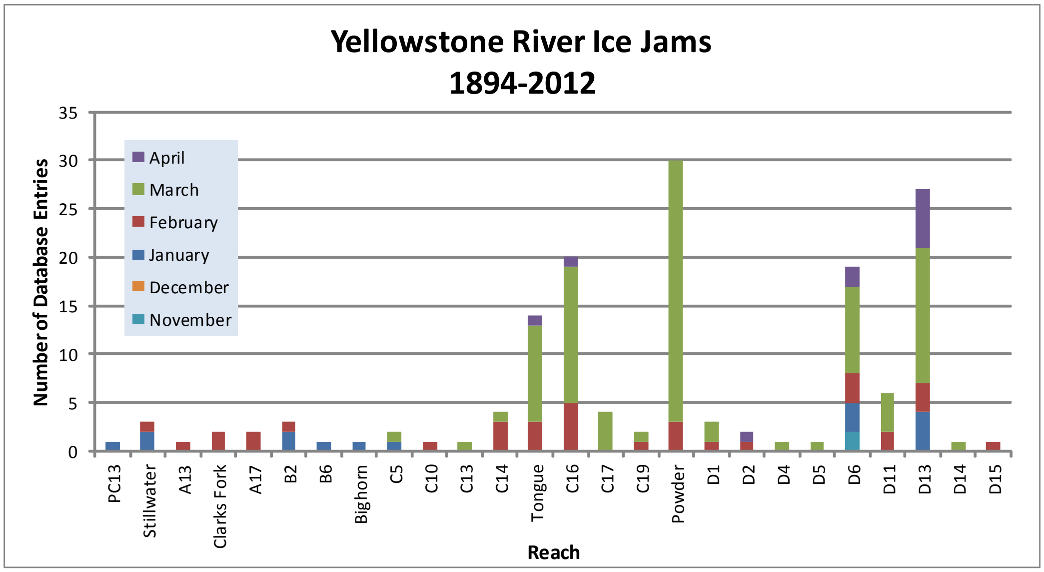
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	2,430	0	417	0	0	0	0	0
Rock RipRap	1,863	0	0	0	0	2,089	0	0
Steel Retaining Wall	0	0	79	0	0	0	0	0
Totals	**4,294**	**0**	**495**	**0**	**0**	**2,089**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	27,141	25,371	1.93	1950 to 1976:	25.94%
1976	27,419	39,394	2.44	1976 to 1995:	-13.93%
1995	26,852	29,464	2.10	1995 to 2001:	9.78%
2001	26,774	34,867	2.30	1950 to 2001:	18.99%
Change 1950 - 2001	**-367**	**9,495**	**0.37**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	4,657

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	23	2.9%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	174	22.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	592		667	
Total Floodplain Area (Ac)	789		691	
Total Isolated (Ac)	**197**	**25.0%**	**24**	**11.3%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	77	0	0	**77**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
229	458	1,082	88	8%	142	108	76%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	2	0.1%
RipRap/Flow Deflectors			
	Other Infrastructure	9	0.7%
	Irrigated	39	3.2%
RipRap			
	Railroad	0	0.0%
	Non-Irrigated	10	0.8%
	Irrigated	48	3.9%
Other			
	Other Infrastructure	8	0.7%
Dike/Levee			
	Non-Irrigated	81	6.6%
	Totals	**196**	**16.0%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
211.2	0.0	8.3	4.1	12.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	63	76	110	128	1.6%	1.9%	2.7%	3.2%
	Totals	**63**	**76**	**110**	**128**	**1.6%**	**1.9%**	**2.7%**	**3.2%**
Agricultural Land									
	Non-Irrigated	2,124	2,011	2,112	2,060	53.2%	50.3%	52.9%	51.6%
	Irrigated	1,161	1,098	947	960	29.1%	27.5%	23.7%	24.0%
	Totals	**3,285**	**3,108**	**3,059**	**3,020**	**82.2%**	**77.8%**	**76.6%**	**75.6%**
Channel									
	Channel	592	588	588	608	14.8%	14.7%	14.7%	15.2%
	Totals	**592**	**588**	**588**	**608**	**14.8%**	**14.7%**	**14.7%**	**15.2%**
ExUrban									
	ExUrban Other	0	3	3	3	0.0%	0.1%	0.1%	0.1%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	7	7	0.0%	0.0%	0.2%	0.2%
	Totals	**0**	**3**	**10**	**10**	**0.0%**	**0.1%**	**0.3%**	**0.3%**
Transportation									
	Public Road	28	52	61	61	0.7%	1.3%	1.5%	1.5%
	Interstate	0	141	141	141	0.0%	3.5%	3.5%	3.5%
	Railroad	27	27	27	27	0.7%	0.7%	0.7%	0.7%
	Totals	**55**	**220**	**229**	**229**	**1.4%**	**5.5%**	**5.7%**	**5.7%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	46	56	0.0%	0.0%	1.5%	1.9%	0.0%	1.5%	0.3%	1.9%
	Flood	1,161	1,098	901	904	35.3%	35.3%	29.5%	29.9%	0.0%	-5.9%	0.5%	-5.4%
	Totals	**1,161**	**1,098**	**947**	**960**	**35.3%**	**35.3%**	**31.0%**	**31.8%**	**0.0%**	**-4.4%**	**0.8%**	**-3.6%**

Non-Irrigated												
Multi-Use	1,955	1,716	1,691	1,658	59.5%	55.2%	55.3%	54.9%	-4.3%	0.1%	-0.4%	-4.6%
Hay/Pasture	169	294	421	402	5.1%	9.5%	13.7%	13.3%	4.3%	4.3%	-0.4%	8.2%
Totals	**2,124**	**2,011**	**2,112**	**2,060**	**64.7%**	**64.7%**	**69.0%**	**68.2%**	**0.0%**	**4.4%**	**-0.8%**	**3.6%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.9	0.3	0.8	2.0	0.6	2.1	6.5	2.2	18.8
Max	47.4	35.9	51.2	59.3	37.9	55.7	11.5	38.6	18.8
Average	8.0	6.4	8.6	14.2	11.5	16.4	9.0	15.3	18.8
Sum	135.4	121.3	172.5	312.5	206.6	296.0	18.0	106.9	18.8

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	107.7
Channel to Riparian (acres)	140.9
Riparian Encroachment (acres)	**33.2**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	0.0
1950s Floodplain Mapped as 2011 Channel (Ac)	5.8
Total Recruitment (1950s to 2011)(Ac)	**5.8**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	14.8	73.1	24.6	0.0	**112.5**
Acres/Valley Mile	3.2	15.7	5.3	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.43	0.02%	0.02	0.08	0.02	0.03

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Sweet Grass	**Upstream River Mile**	438.5
Classification	UA: Unconfined anabranching	**Downstream River Mile**	434.7
General Location	Reed Point	**Length**	3.80 mi (6.12 km)

General Comments Near Reed Point, Reach A9 provides a good example of a largely unmodified, dynamic river segment.

Narrative Summary

Reach A9 is located in lowermost Sweet Grass County, just upstream of the Sweet Grass/Stillwater county line near Reed Point. The reach is an Unconfined Anabranching reach type. The reach is 3.8 miles long, extending from RM 434.7 to RM 438.5. The lower reach break is the bridge crossing just north of Reed Point. This bridge was originally constructed in 1911 and rebuilt in 2000.

Reach A9 provides an excellent example of a dynamic, largely unmodified Unconfined Anabranching reach type. The stream corridor is typically one half mile wide through the reach, with significant narrowing of that corridor in the downstream direction as the river approaches the bridge at Reed Point. In the uppermost portion of the Reach (RM 437-438.5), the northern valley margin consists of an alluvial fan deposit that is currently irrigated with center pivots. Downstream, the river abuts Cretaceous-age Hell Creek Formation on the northern valley wall, which contains sandstones that tend to form steep cliffs. The reach is characterized by high displacement ratios, extensive split flow and islands, and riparian turnover. Although riparian turnover is evident, the rates of that turnover have gone down in the reach since 1976. Prior to that time (1950-1976), average turnover rates were 5.9 acres per year; from 1976 to 2001 that average rate dropped to 3.6 acres of riparian turnover per year.

Bank armor in Reach A9 consists primarily of 10,000 linear feet of riprap which drapes about 24 percent of the stream bank. About 2,000 feet of that armor was constructed since 2001. This new armor is on the right bank at RM 437.8 where the river was rapidly migrating southward toward the rail line. By the time the bank was armored, the river was within 60 feet of the tracks.

Much of the riprap in Reach A9 is located along the south bank of the river on lower end of the reach where the Yellowstone River approaches the bridge near Reed Point. This bridge marks a major narrowing of the river corridor from about 2,000 feet wide ½ mile upstream of the bridge to 360 feet at the bridge itself. The narrowing is achieved by a ~mile long section of bank armor on the right bank that on its lower end runs due north/south, which is perpendicular to the overall east/west trend of the river. This has caused the river to consolidate into a main thread and abandon an historic side channel just upstream of the bridge at the Indian Fort Fishing Access Site.

Reach A9 has experienced the loss of almost about 3,700 feet of side channel since the 1950s due to dike construction. All of the side channel loss is from one project at the upstream end of the reach, where a side channel was blocked on the north side of the river at RM 438.5.

Even though Reach A9 has experienced some side channel loss, it still supports extensive side channel length. As of 2001 there were 5.1 miles of active side channel in the 3.8 mile long reach. Large islands have persisted in the reach since 1950.

Land use in Reach A9 is predominantly agricultural, although there several hundred acres of non-agricultural uses due to the proximity of the transportation corridor as well as the town of Reed Point. Since 1950, 160 acres of agricultural land have been converted to pivot. A total of 300 acres of developed land are in the Channel Migration Zone. Most of that is in flood irrigation (250 acres), but 40 acres are in transportation. About 13 percent of the CMZ is restricted by physical features.

There is natural gas one pipeline that crosses under the Yellowstone River in Reach A9. It crosses at the upper most end of the reach at RM 438.5 and is consists of a 6 inch pipeline that is owned by Northwestern Energy.

Since 1950, Reach A9 has lost most of its forest that would be considered at low risk of cowbird infestation due to its separation from agricultural infrastructure. In 1950, about 17 acres of forest per valley mile were identified as low risk and by 2001 that forest area had been reduced to 2.5 acres due to development within the reach.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 14,000 cfs to 13,300 cfs, a drop of about 5 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,030 cfs to 1,680 cfs with human development, a reduction of 17 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

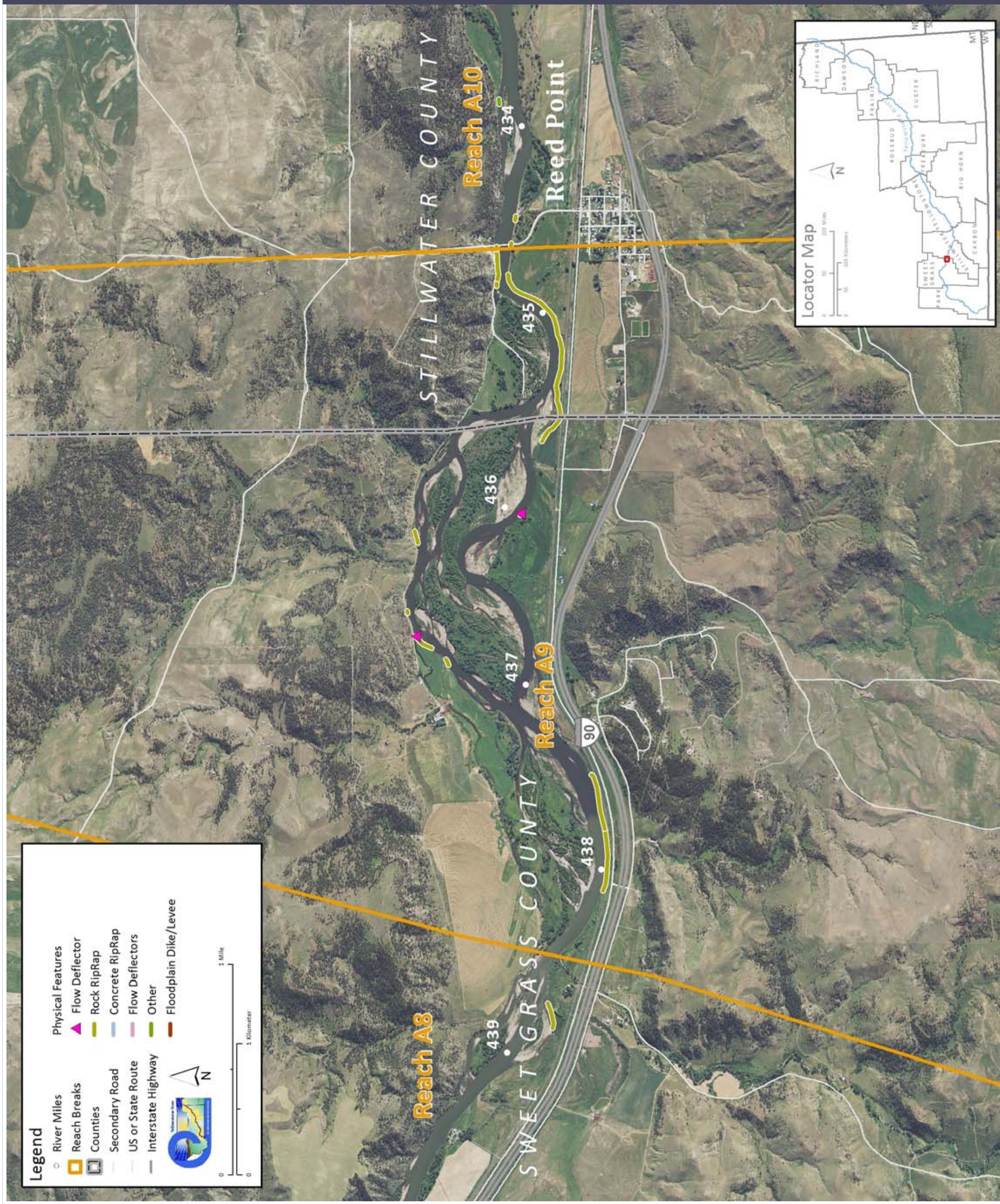
The reduction in flows is evident by the contraction of the 5-year floodplain area in Reach A9 by 15 acres, or 6 percent.

CEA-Related observations in Reach A9 include:
•Reduced floodplain turnover rates since 1976
•Approximately 3,700 feet of side channel has been lost due to channel plugging between 1950 and 2011
•Meander belt encroachment at bridge crossing
•Side channel loss as part of armoring at bridge approach

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A9 include:
•Side channel restoration at RM 438.5

- CMZ management due to extent of CMZ restriction (13 percent)
- Pipeline management for 6-inch natural gas pipeline that crosses under the river at RM 438.5

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	70.3	68.1

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	14,000	27,100	33,900	38,000	46,500	49,900	57,600	2,030	1,760
Regulated	13,300	26,300	33,100	37,300	45,900	49,400	57,300	1,680	1,680
% Change	-5.00%	-2.95%	-2.36%	-1.84%	-1.29%	-1.00%	-0.52%	-17.24%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	6/15/1951	B/W	1:28,400	6192500	13700
1976	USCOE	9/28/1976	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	9/11/96 - 8/28/97	B/W	NA	6192500	2560
2001	NRCS	8/2/2001 - 8/8/2001	CIR	1:24,000	6192500	2000
2005	NAIP	07/27/2005	color	1-meter pixels	6192500	3540
2007	Woolpert	10/15/2007 - 11/2/2007	Color	NA	6192500	1410-2090
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	NAIP	8/22/2011	Color	1-meter pixels	6192500	5480
2011	NAIP	7/24/2011	Color	1-meter pixels	6192500	13100
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	7,886	19.2%	9,898	24.2%	2,012
	Flow Deflectors	0	0.0%	107	0.3%	107
	Feature Type Totals	**7,886**	**19.2%**	**10,005**	**24.4%**	**2,120**
Floodplain Control						
	Transportation Encroachment	6,033	14.7%	6,033	14.7%	0
	Feature Type Totals	**6,033**	**14.7%**	**6,033**	**14.7%**	**0**
	Reach Totals	**13,918**	**34.0%**	**16,038**	**39.1%**	**2,120**

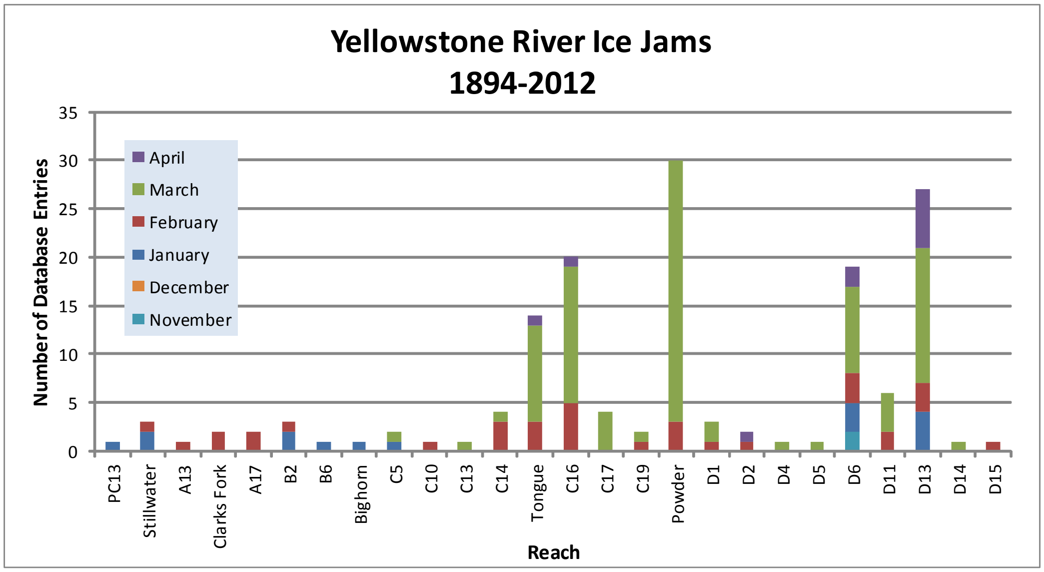
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	5,592	0	0	928	0	492	0	0
Totals	**5,592**	**0**	**0**	**928**	**0**	**492**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	23,308	30,404	2.30	1950 to 1976:	20.79%
1976	20,291	36,191	2.78	1976 to 1995:	-13.08%
1995	20,903	29,673	2.42	1995 to 2001:	-4.64%
2001	20,490	26,786	2.31	1950 to 2001:	0.12%
Change 1950 - 2001	**-2,818**	**-3,618**	**0.00**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	3,717

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	19	3.5%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	522		629	
Total Floodplain Area (Ac)	541		644	
Total Isolated (Ac)	**19**	**3.5%**	**15**	**6.2%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	90	0	0	**90**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
360	720	1,109	151	14%	41	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	3	0.3%
RipRap			
	Railroad	148	12.8%
	Totals	**151**	**13.1%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
252.0	0.0	4.3	2.8	40.1

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	28	17	24	27	1.0%	0.6%	0.9%	1.0%
	Totals	**28**	**17**	**24**	**27**	**1.0%**	**0.6%**	**0.9%**	**1.0%**
Agricultural Land									
	Non-Irrigated	1,547	1,441	1,319	1,146	56.7%	52.8%	48.3%	42.0%
	Irrigated	463	450	491	614	17.0%	16.5%	18.0%	22.5%
	Totals	**2,009**	**1,891**	**1,809**	**1,760**	**73.6%**	**69.3%**	**66.3%**	**64.5%**
Channel									
	Channel	622	624	622	657	22.8%	22.9%	22.8%	24.1%
	Totals	**622**	**624**	**622**	**657**	**22.8%**	**22.9%**	**22.8%**	**24.1%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	9	45	67	0.0%	0.3%	1.7%	2.5%
	Totals	**0**	**9**	**45**	**67**	**0.0%**	**0.3%**	**1.7%**	**2.5%**
Transportation									
	Public Road	33	45	44	44	1.2%	1.6%	1.6%	1.6%
	Interstate	0	104	104	104	0.0%	3.8%	3.8%	3.8%
	Railroad	21	21	21	21	0.8%	0.8%	0.8%	0.8%
	Totals	**54**	**170**	**169**	**169**	**2.0%**	**6.2%**	**6.2%**	**6.2%**
Urban									
	Urban Other	0	0	2	2	0.0%	0.0%	0.1%	0.1%
	Urban Residential	16	11	16	16	0.6%	0.4%	0.6%	0.6%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	14	2	0.0%	0.0%	0.5%	0.1%
	Urban Industrial	0	6	28	27	0.0%	0.2%	1.0%	1.0%
	Totals	**16**	**17**	**59**	**48**	**0.6%**	**0.6%**	**2.2%**	**1.8%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	146	163	0.0%	0.0%	8.1%	9.3%	0.0%	8.1%	1.2%	9.3%
	Flood	463	450	345	451	23.0%	23.8%	19.0%	25.6%	0.8%	-4.8%	6.6%	2.6%
	Totals	**463**	**450**	**491**	**614**	**23.0%**	**23.8%**	**27.1%**	**34.9%**	**0.8%**	**3.3%**	**7.8%**	**11.9%**

Non-Irrigated													
Multi-Use	1,359	1,319	1,134	1,027	67.6%	69.7%	62.7%	58.4%	2.1%	-7.1%	-4.3%	-9.3%
Hay/Pasture	187	122	185	119	9.3%	6.5%	10.2%	6.8%	-2.9%	3.8%	-3.5%	-2.6%
Totals	**1,547**	**1,441**	**1,319**	**1,146**	**77.0%**	**76.2%**	**72.9%**	**65.1%**	**-0.8%**	**-3.3%**	**-7.8%**	**-11.9%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.7	0.3	0.8	0.4	0.6	2.2	4.6	1.9	5.2
Max	15.5	18.6	30.1	60.7	53.8	71.0	53.8	15.6	50.1
Average	4.5	3.8	7.2	14.8	14.7	22.8	21.8	8.7	27.8
Sum	49.3	67.6	93.5	148.2	191.4	228.3	130.6	52.3	83.5

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	81.4
Channel to Riparian (acres)	126.5
Riparian Encroachment (acres)	**45.1**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	0.0
1950s Floodplain Mapped as 2011 Channel (Ac)	5.8
Total Recruitment (1950s to 2011)(Ac)	**5.8**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	9.8	32.5	30.9	0.0	**73.2**
Acres/Valley Mile	2.9	9.7	9.2	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.07	0.01%	0.02	0.00	0.02	0.02

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Stillwater	**Upstream River Mile**	434.7
Classification	PCS: Partially confined straight	**Downstream River Mile**	430.3
General Location	Reed Point	**Length**	4.40 mi (7.08 km)
General Comments	Channel closely follows left valley wall		

Narrative Summary

Reach A10 is 4.4 miles long and begins at Reed Point. The reach is a Partially Confined Straight (PCS) reach type, indicating valley wall influences and minimal meandering. The river flows closely along the north valley wall sandstones of the Hell Creek Formation. Migration activity to the south off of the valley wall has been limited and relatively slow, resulting in a fairly narrow Channel Migration Zone and relatively little bank armor. There is only 500 feet of bank armor in the reach, which protects less than 2 percent of the bankline.
No side channels have been physically blocked in Reach A10, however there still has been a net loss of almost 2 miles of side channel length since 1950. This is in part due to the loss of a several thousand foot side channel on the south side of the corridor at RM 431. The entrance to the side channel is just downstream of a series of flow deflectors that appear to have contributed to aggradation at the entrance to the side channel.

Riparian mapping in Reach A10 shows a reduction in total acreage of closed timber from 222 acres in 1950 to 155 acres in 2001.

One of the most evident impacts in Reach A10 is floodplain isolation. Due to the transportation encroachment into the reach by the rail line, approximately 30 percent of the 100 year floodplain has become isolated from the river.

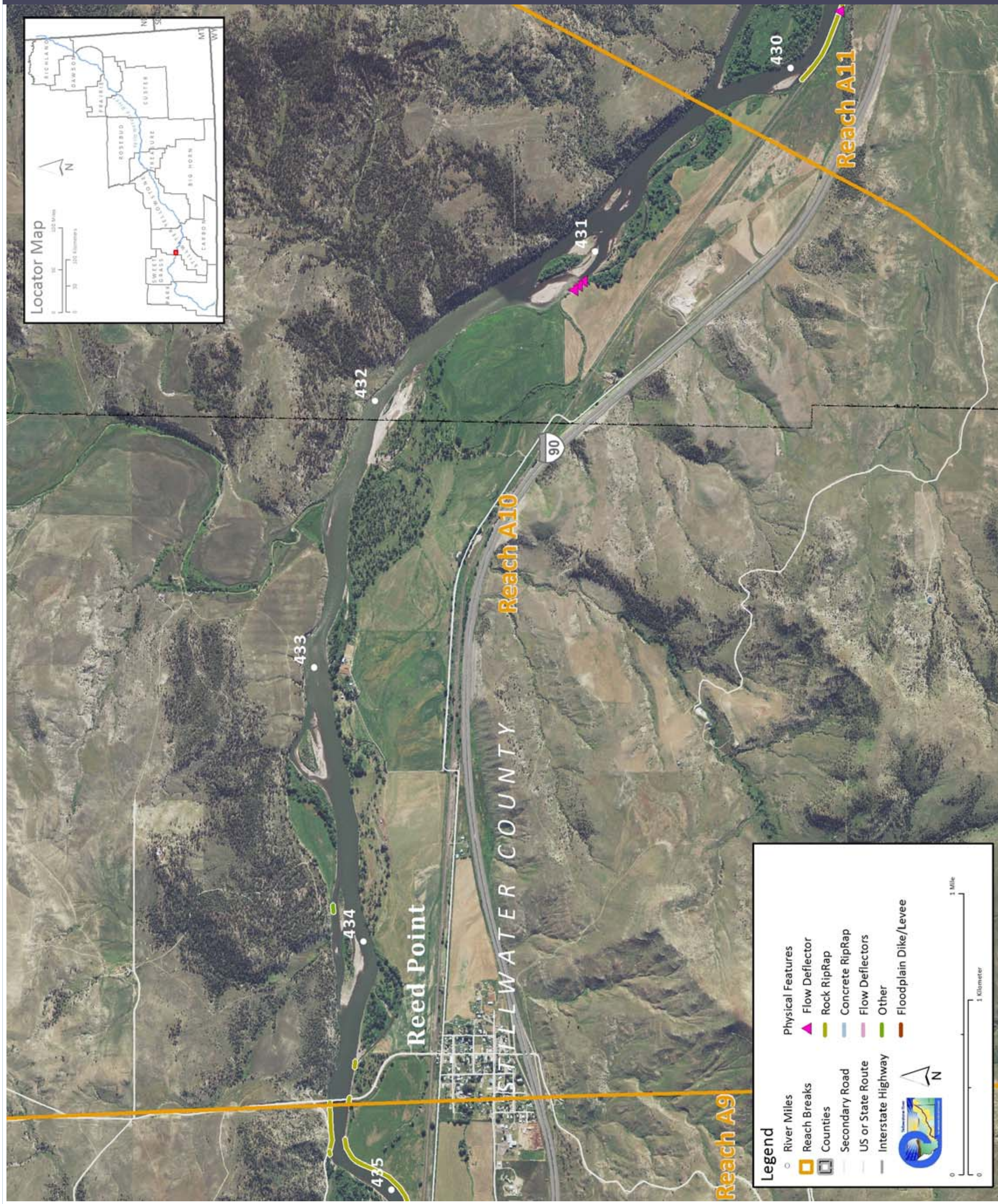
Land use in Reach A10 is predominantly agricultural, although there several hundred acres of non-agricultural uses due to the proximity of the transportation corridor as well as the town of Reed Point. All of the irrigated land is in flood. A total of 163 acres of developed land are in the Channel Migration Zone. Almost all of that ground is in flood irrigation. Less than 1 percent of the CMZ is restricted by physical features.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 14,000 cfs to 13,300 cfs, a drop of about 5 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,060 cfs to 1,690 cfs with human development, a reduction of 18 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A10 include:
•Passive loss of anabranching channels, some potentially correlated to flow deflectors
•Floodplain isolation by active rail line.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A10 include:
•Floodplain restoration/reconnection behind rail line at RM 430.1
•Side channel restoration at RM 431

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	65.9	71.9

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	14,000	27,100	33,900	38,000	46,500	49,900	57,600	2,060	1,760
Regulated	13,300	26,300	33,100	37,300	45,900	49,400	57,300	1,690	1,680
% Change	-5.00%	-2.95%	-2.36%	-1.84%	-1.29%	-1.00%	-0.52%	-17.96%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	15-Jun-51	B/W	1:28,400	6192500	13700
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	28-Aug-97	B/W		6192500	4430
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2004	Merrick	14-May-04	Color	1:15,840	6192500	4520
2005	NAIP	07/27/2005	color	1-meter pixels	6192500	3540
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	USCOE	October 2012	color	1-ft pixel	6192500	2530
2011	NAIP	8/22/2011	Color	1-meter pixels	6192500	5480
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	187	0.4%	270	0.6%	82
	Flow Deflectors	0	0.0%	68	0.2%	68
	Car Bodies	136	0.3%	136	0.3%	0
	Between Flow Deflectors	0	0.0%	187	0.4%	187
	Feature Type Totals	**323**	**0.7%**	**661**	**1.5%**	**338**
Floodplain Control						
	Transportation Encroachment	3,650	8.1%	3,650	8.1%	0
	Feature Type Totals	**3,650**	**8.1%**	**3,650**	**8.1%**	**0**
	Reach Totals	**3,973**	**8.8%**	**4,311**	**9.6%**	**338**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Car Bodies	0	134	0	0	0	0	0	0
Rock RipRap	0	33	0	95	0	0	0	0
Totals	**0**	**167**	**0**	**95**	**0**	**0**	**0**	**0**

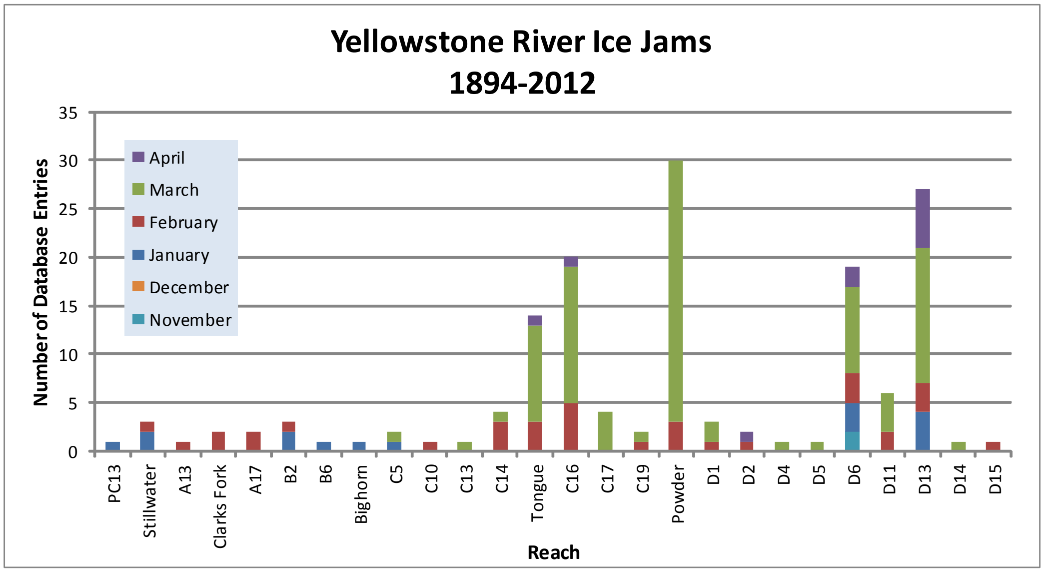
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Stream Stabilization							
	Rock RipRap	0	64	64	353	353	353
	Car Bodies	0	0	0	0	175	175
	Totals	**0**	**64**	**64**	**353**	**528**	**528**
Transportation Encroachment							
	Railroad	19,892	19,892	19,892	19,892	19,892	19,892
	Interstate	0	6,852	6,852	6,852	6,852	6,852
	County Road	11,122	13,828	13,828	13,828	13,828	13,828
	Bridge Approach	1,778	1,763	1,763	1,940	1,940	1,940
	Totals	**32,792**	**42,335**	**42,335**	**42,512**	**42,512**	**42,512**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	22,613	20,949	1.93	1950 to 1976:	-6.87%
1976	22,331	17,734	1.79	1976 to 1995:	-27.05%
1995	22,532	6,960	1.31	1995 to 2001:	10.93%
2001	22,534	10,185	1.45	1950 to 2001:	-24.63%
Change 1950 - 2001	**-79**	**-10,764**	**-0.47**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	91	14.1%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	101	15.6%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	454		321	
Total Floodplain Area (Ac)	646		329	
Total Isolated (Ac)	**192**	**29.6%**	**8**	**21.7%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	5	0	0	**5**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
182	365	543	6	1%	133	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	6	0.9%
	Totals	**6**	**0.9%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
160.8	0.0	0.0	0.0	2.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	23	16	22	28	0.8%	0.5%	0.8%	0.9%
	Totals	**23**	**16**	**22**	**28**	**0.8%**	**0.5%**	**0.8%**	**0.9%**
Agricultural Land									
	Non-Irrigated	1,915	1,825	1,816	1,773	64.0%	61.0%	60.7%	59.3%
	Irrigated	636	604	602	597	21.3%	20.2%	20.1%	20.0%
	Totals	**2,551**	**2,429**	**2,418**	**2,371**	**85.2%**	**81.2%**	**80.8%**	**79.2%**
Channel									
	Channel	317	319	313	349	10.6%	10.7%	10.5%	11.7%
	Totals	**317**	**319**	**313**	**349**	**10.6%**	**10.7%**	**10.5%**	**11.7%**
ExUrban									
	ExUrban Other	0	17	26	26	0.0%	0.6%	0.9%	0.9%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	1	4	0.0%	0.0%	0.0%	0.1%
	Totals	**0**	**17**	**27**	**30**	**0.0%**	**0.6%**	**0.9%**	**1.0%**
Transportation									
	Public Road	33	27	27	27	1.1%	0.9%	0.9%	0.9%
	Interstate	0	109	109	109	0.0%	3.6%	3.6%	3.6%
	Railroad	22	22	22	22	0.8%	0.7%	0.7%	0.7%
	Totals	**55**	**158**	**158**	**158**	**1.8%**	**5.3%**	**5.3%**	**5.3%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	46	44	44	44	1.5%	1.5%	1.5%	1.5%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	9	9	12	0.0%	0.3%	0.3%	0.4%
	Totals	**46**	**53**	**53**	**56**	**1.5%**	**1.8%**	**1.8%**	**1.9%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	636	604	602	597	24.9%	24.9%	24.9%	25.2%	-0.1%	0.0%	0.3%	0.3%
	Totals	**636**	**604**	**602**	**597**	**24.9%**	**24.9%**	**24.9%**	**25.2%**	**-0.1%**	**0.0%**	**0.3%**	**0.3%**

Non-Irrigated												
Multi-Use	1,724	1,671	1,777	1,663	67.6%	68.8%	73.5%	70.2%	1.2%	4.7%	-3.3%	2.6%
Hay/Pasture	191	154	40	110	7.5%	6.3%	1.6%	4.6%	-1.2%	-4.7%	3.0%	-2.8%
Totals	**1,915**	**1,825**	**1,816**	**1,773**	**75.1%**	**75.1%**	**75.1%**	**74.8%**	**0.1%**	**0.0%**	**-0.3%**	**-0.3%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.7	0.2	1.5	1.6	0.5	2.9	1.3	12.4	1.9
Max	20.8	7.1	14.5	57.2	81.3	81.9	5.9	12.4	38.4
Average	8.5	2.9	4.5	17.1	14.0	19.3	3.2	12.4	11.6
Sum	51.2	20.4	27.0	221.9	210.2	154.8	9.6	12.4	69.4

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	44.1
Channel to Riparian (acres)	41.6
Riparian Encroachment (acres)	**-2.5**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	0.3	15.9	6.4	0.0	**22.6**
Acres/Valley Mile	0.1	3.9	1.6	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.05	0.00%	0.00	0.00	0.01	0.03

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Stillwater	**Upstream River Mile**	430.3
Classification	PCB: Partially confined braided	**Downstream River Mile**	423.3
General Location	I-90 bridge crossing	**Length**	7.00 mi (11.27 km)
General Comments	High right bank terrace with bedrock toe; I-90 bridge crossing		

Narrative Summary

Reach A11 is seven miles long and is located at the I-90 Bridge crossing below Reed Point. The reach is a Partially Confined Braided (PCB) reach type, indicating valley wall influences and relatively extensive open gravel bars and small islands. The valley is relatively narrow in this reach, and the river swings from the north valley wall upstream of the bridge to the south valley wall downstream. The valley wall consists of erosion-resistant sandstone cliffs of the Hell Creek Formation. The river has been extremely dynamic in this reach, and over a thousand feet of bank armor has been flanked since 2001. Since 1950, numerous areas have experienced over 500 feet of bank movement.

Similar to other reaches in Region A, the overall footprint of the river channel has increased in size since 1950. In 1950, the channel footprint was 451 acres but by 2001 it had expanded to 567 acres.

About 13 percent of the banks in Reach A11 are armored, with the majority of that armor being rock riprap. Between 2001 and 2011, there was a loss of about 1,200 feet of armor in the reach. Rock riprap was eroded out from the left (north) bank at RM 424.5, where the river flanked about a thousand feet of rock between 2005 and 2011. Since that time, the river has migrated at least 250 feet behind the armor. At least one flow deflector was lost on the same bankline just upstream. About 320 feet of the lost bank protection was flow deflectors.

Over a mile of side channels have been physically blocked in Reach A11 since 1950. The loss has occurred at RM 424, where a road/field dike crosses the old side channel at two locations.

Land use in Reach A11 is predominantly agricultural, although there several hundred acres of transportation-related use associated with I-90 and the rail line. All of the irrigated land is in under flood irrigation. A total of 210 acres of developed land are in the Channel Migration Zone. Almost all of that ground is in flood irrigation, and about 50 acres of the transportation corridor are within the CMZ. About 17 percent of the CMZ is isolated by physical features.

There is one diversion structure on the right bank at RM 428.3 that feeds the Merrill Columbus Ditch. The diversion is located just downstream of the railroad and county road bridges, which are about 2,100 feet upstream of the I-90 Bridge.

There is one dump site mapped in Reach A11 at RM 425.8.

Riparian mapping in Reach A11 shows a reduction in total acreage of closed timber from 400 acres in 1950 to 230 acres in 2001. Similarly, the extent of mapped shrubs dropped from 170 acres to 82 acres for the same timeframe.

Reach A11 was sampled as part of the avian study. The average species richness in Reach A11 was 9.6, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for all sites evaluated is 8. One bird Species of Concern (SOC), the Bobolink, was identified in the reach. One bird species identified by the Montana Natural Heritage Program as a Potential Species of Concern (PSOC), the Ovenbird, was also found.

Since 1950, Reach A11 has lost most of its forest that would be considered at low risk of cowbird infestation due to its separation from agricultural infrastructure. In 1950, about 35 acres of forest per valley mile were identified as low risk and by 2001 that forest area had been reduced to 13 acres due to development within the reach.

Reach A11 marks a distinct jump in the extent of Russian olive present in the river corridor. The reach has approximately 2.3 acres of mapped Russian olive, which is most concentrated in the vicinity of the bridges.

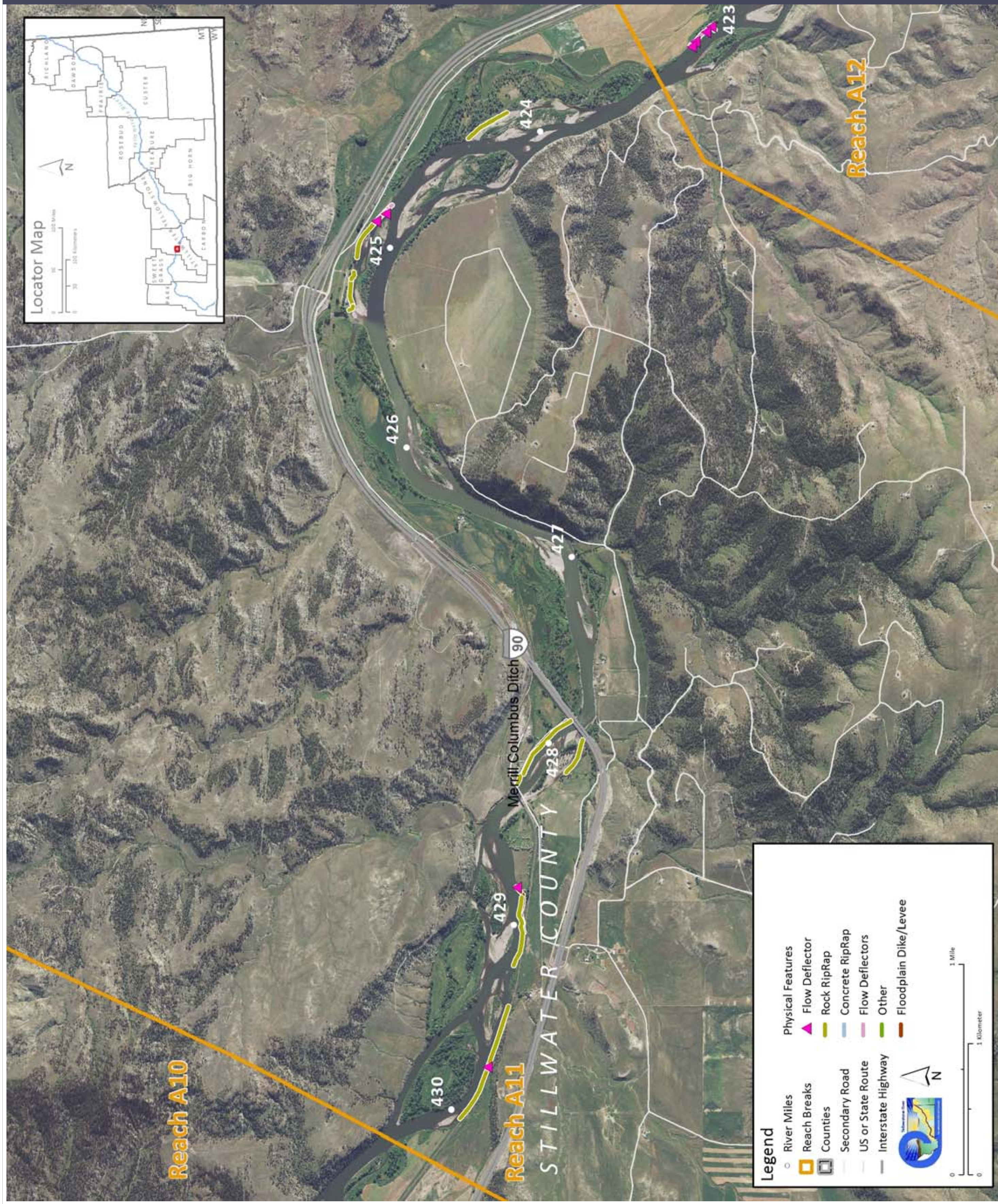
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 14,200 cfs to 13,400 cfs, a drop of about 6 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,070 cfs to 1,690 cfs with human development, a reduction of 18 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A11 include:
•Accelerated erosion behind 1,000 feet of flanked rock riprap.
•Blockage of several thousand feet of side channel
•At least one flanked barb
•Expansion of Russian olive infestation relative to upstream.
•Reduction in both closed timber and shrub riparian extent.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A11 include:
•Floodplain restoration/reconnection behind rail line at RM 430

- •Side channel restoration at RM 424
- •Bank armor removal at RM 424.5
- •CMA management due to extent of CMZ restriction (17 percent)
- •Russian olive removal—this is the most upstream reach of major Russian olive colonization
- •Solid waste removal from right (south) bank area at RM 425.8
- •Irrigation diversion structure management at Merrill Columbus Ditch Diversion at RM 428.3

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	58.9	76.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	14,200	27,500	34,400	38,600	47,200	50,600	58,500	2,070	1,760
Regulated	13,400	26,700	33,600	37,800	46,600	50,100	58,200	1,690	1,680
% Change	-5.63%	-2.91%	-2.33%	-2.07%	-1.27%	-0.99%	-0.51%	-18.36%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	15-Jun-51	B/W	1:28,400	6192500	13700
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	8/28/97 - 9/10/96	B/W		6192500	4430
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2004	Merrick	14-May-04	Color	1:15,840	6192500	4520
2005	NAIP	07/27/2005	color	1-meter pixels	6192500	3540
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	USCOE	October 2012	color	1-ft pixel	6192500	2530
2011	NAIP	8/22/2011	Color	1-meter pixels	6192500	5480
2011	NAIP	7/24/2011	Color	1-meter pixels	6192500	13100
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	10,657	14.5%	9,701	13.2%	-956
	Flow Deflectors	104	0.1%	286	0.4%	183
	Between Flow Deflectors	504	0.7%	0	0.0%	-504
	Feature Type Totals	**11,264**	**15.3%**	**9,987**	**13.6%**	**-1,277**
Floodplain Control						
	Transportation Encroachment	14,288	19.4%	14,288	19.4%	0
	Floodplain Dike/Levee	2,719	3.7%	2,719	3.7%	0
	Feature Type Totals	**17,007**	**23.1%**	**17,007**	**23.1%**	**0**
	Reach Totals	**28,271**	**38.4%**	**26,994**	**36.7%**	**-1,277**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	574	0	0	0	0	0	0	0
Rock RipRap	0	1,794	1,794	98	1,155	5,845	0	0
Totals	**574**	**1,794**	**1,794**	**98**	**1,155**	**5,845**	**0**	**0**

Bankline/Floodplain Inventory: Time Series

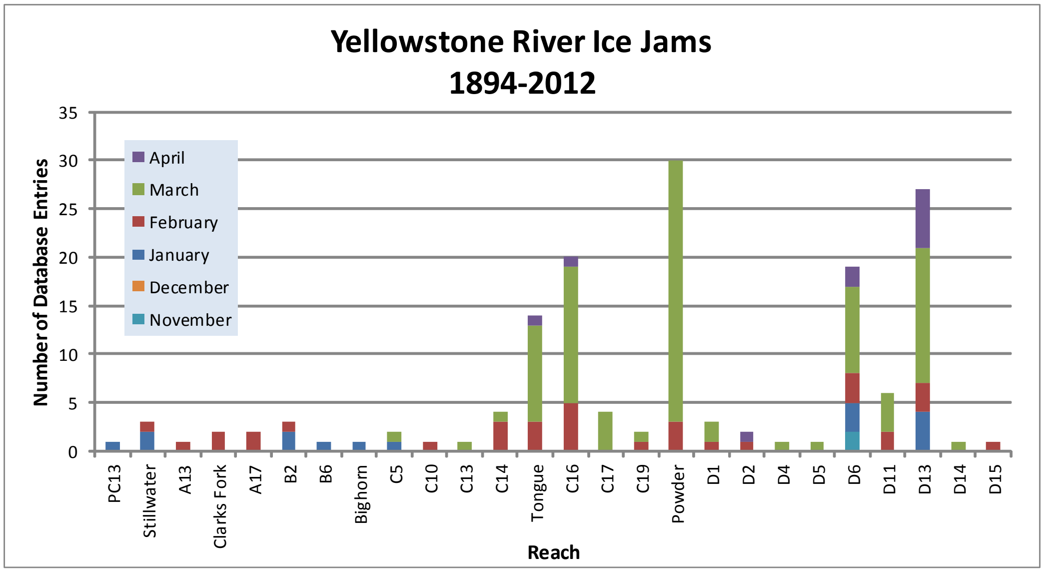
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	In Channel Diversion	0	0	177	177	177	177
	Floodplain Dike/Levee	10,420	10,420	10,420	10,420	10,420	10,420
	Totals	**10,420**	**10,420**	**10,597**	**10,597**	**10,597**	**10,597**
Other Off Channel							
	Floodplain Dike/Levee	0	1,744	1,744	1,744	1,744	1,744
	Floodplain Dike/Levee	671	671	671	671	671	671
	Totals	**671**	**2,415**	**2,415**	**2,415**	**2,415**	**2,415**
Stream Stabilization							
	Rock RipRap	3,808	10,376	10,937	11,983	12,206	12,206
	Flow Deflector	0	262	283	283	283	283
	Totals	**3,808**	**10,638**	**11,219**	**12,266**	**12,489**	**12,489**
Transportation Encroachment							
	Railroad	23,386	23,386	23,386	23,386	23,386	23,386

Interstate	0	5,091	5,091	5,091	5,091	5,091
County Road	10,422	10,422	10,422	10,422	10,422	10,422
Bridge Approach	3,345	5,638	5,638	5,638	5,638	5,638
Totals	**37,153**	**44,536**	**44,536**	**44,536**	**44,536**	**44,536**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	36,794	31,217	1.85	1950 to 1976:	-10.45%
1976	36,443	23,878	1.66	1976 to 1995:	-2.84%
1995	37,100	22,564	1.61	1995 to 2001:	1.16%
2001	36,818	23,078	1.63	1950 to 2001:	-11.99%
Change 1950 - 2001	**24**	**-8,139**	**-0.22**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	6,747

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	39	5.4%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	678		752	
Total Floodplain Area (Ac)	717		802	
Total Isolated (Ac)	**39**	**5.4%**	**50**	**21.3%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	1	0	0	**1**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
342	684	1,411	256	18%	65	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	34	2.3%
	Interstate	8	0.5%
	Canal	8	0.6%
RipRap			
	Railroad	81	5.4%
	Other Infrastructure	66	4.4%
	Interstate	15	1.0%
	Canal	24	1.7%
	Totals	**236**	**15.9%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
153.0	0.0	0.0	9.0	48.7

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	35	34	35	35	1.0%	1.0%	1.0%	1.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	14	25	47	73	0.4%	0.7%	1.3%	2.0%
	Totals	**49**	**59**	**82**	**108**	**1.4%**	**1.7%**	**2.3%**	**3.0%**
Agricultural Land									
	Non-Irrigated	2,521	2,099	2,003	1,826	70.4%	58.6%	55.9%	51.0%
	Irrigated	351	515	468	531	9.8%	14.4%	13.1%	14.8%
	Totals	**2,872**	**2,614**	**2,470**	**2,357**	**80.2%**	**73.0%**	**69.0%**	**65.8%**
Channel									
	Channel	564	615	681	718	15.8%	17.2%	19.0%	20.1%
	Totals	**564**	**615**	**681**	**718**	**15.8%**	**17.2%**	**19.0%**	**20.1%**
ExUrban									
	ExUrban Other	0	3	7	7	0.0%	0.1%	0.2%	0.2%
	ExUrban Undeveloped	0	0	10	18	0.0%	0.0%	0.3%	0.5%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	14	45	0.0%	0.0%	0.4%	1.3%
	Totals	**0**	**3**	**31**	**71**	**0.0%**	**0.1%**	**0.9%**	**2.0%**
Transportation									
	Public Road	56	41	69	79	1.6%	1.1%	1.9%	2.2%
	Interstate	0	208	208	208	0.0%	5.8%	5.8%	5.8%
	Railroad	39	39	39	39	1.1%	1.1%	1.1%	1.1%
	Totals	**94**	**288**	**316**	**327**	**2.6%**	**8.1%**	**8.8%**	**9.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	351	515	468	531	12.2%	19.7%	18.9%	22.5%	7.5%	-0.7%	3.6%	10.3%
	Totals	**351**	**515**	**468**	**531**	**12.2%**	**19.7%**	**18.9%**	**22.5%**	**7.5%**	**-0.7%**	**3.6%**	**10.3%**

Non-Irrigated												
Multi-Use	2,024	1,831	1,835	1,637	70.5%	70.1%	74.3%	69.5%	-0.4%	4.2%	-4.8%	-1.0%
Hay/Pasture	497	268	168	189	17.3%	10.3%	6.8%	8.0%	-7.1%	-3.5%	1.2%	-9.3%
Totals	**2,521**	**2,099**	**2,003**	**1,826**	**87.8%**	**80.3%**	**81.1%**	**77.5%**	**-7.5%**	**0.7%**	**-3.6%**	**-10.3%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.5	0.0	0.9	0.4	1.1	0.1	2.4	3.1	10.8
Max	44.8	29.4	25.3	171.9	58.2	100.1	15.5	34.2	39.4
Average	14.2	6.5	5.4	22.0	13.0	12.7	8.2	13.9	23.2
Sum	170.4	137.5	81.6	396.8	194.3	229.1	65.3	97.3	93.0

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	162.2
Channel to Riparian (acres)	97.0
Riparian Encroachment (acres)	**-65.2**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	0.0
1950s Floodplain Mapped as 2011 Channel (Ac)	9.6
Total Recruitment (1950s to 2011)(Ac)	**9.6**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	20.2	28.3	30.2	0.0	**78.7**
Acres/Valley Mile	3.2	4.6	4.9	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	2.28	0.14%	0.03	0.42	0.18	0.13

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern Potential Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
✓	✓	American Robin		✓	Chipping Sparrow			Killdeer	✓	✓	Song Sparrow
✓	✓	American Crow	✓	✓	Clay-collared Sparrow			Lark Bunting			Spotted Sandpiper
✓	✓	American Goldfinch		✓	Cliff Swallow	✓	✓	Lark Sparrow	✓	✓	Spotted Towhee
		American Kestrel	✓	✓	Common Grackle	✓	✓	Lazuli Bunting			Sharp-shinned Hawk
✓	✓	American Redstart			Common Merganser	✓	✓	Least Flycatcher		✓	Swainson's Thrush
		Bald Eagle			Common Nighthawk			Mallard			Sandhill Crane
✓	✓	Baltimore Oriole			Common Raven	✓	✓	Mountain Bluebird	✓	✓	Tree Swallow
	✓	Barn Swallow	✓	✓	Common Yellowthroat	✓	✓	Mourning Dove			Turkey Vulture
		Belted Kingfisher			Cooper's Hawk	✓	✓	Northern Flicker			Upland Sandpiper
		Black-billed Cuckoo		✓	Dickcissel			Orchard Oriole	✓	✓	Vesper Sparrow
✓	✓	Black-billed Magpie	✓	✓	Downy Woodpecker			Osprey	✓	✓	Violet-green Swallow
✓	✓	Black-capped Chickadee			Eastern Bluebird	✓	✓	Ovenbird	✓	✓	Warbling Vireo
	✓	Black-and-white Warbler	✓	✓	Eastern Kingbird			Plumbeous Vireo		✓	Western Kingbird
✓	✓	Black-headed Grosbeak			Eurasian Collared-dove			Red-headed Woodpecker	✓	✓	Western Meadowlark
✓	✓	Blue Jay	✓	✓	European Starling	✓	✓	Red-naped Sapsucker	✓	✓	Western Wood-pewee
✓	✓	Bobolink		✓	Field Sparrow			Red Crossbill	✓	✓	White-breasted Nuthatch
✓	✓	Brewer's Blackbird			Franklin's Gull			Ring-necked Pheasant		✓	White-throated Swift
✓	✓	Brown-headed Cowbird			Grasshopper Sparrow			Red-tailed hawk			Wild Turkey
		Brown Creeper	✓	✓	Gray Catbird			Rock Dove			Wood Duck
✓	✓	Brown Thrasher			Great Blue Heron	✓	✓	Red-winged Blackbird			Yellow-bellied Sapsucker
✓	✓	Bullock's Oriole			Great Horned Owl		✓	Red-eyed Vireo			Yellow-billed Cuckoo
		Canada Goose	✓	✓	Hairy Woodpecker			Red-breasted Grosbeak	✓	✓	Yellow-breasted Chat
✓	✓	Cedar Waxwing			House Finch			Say's Phoebe	✓	✓	Yellow-headed Blackbird
	✓	Chimney Swift	✓	✓	House Wren	✓	✓	Savannah Sparrow	✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Stillwater	**Upstream River Mile**	423.3
Classification	PCB: Partially confined braided	**Downstream River Mile**	417.3
General Location	To Stillwater confluence	**Length**	6.00 mi (9.66 km)
General Comments	To Stillwater confluence		

Narrative Summary

Reach A12 is seven miles long and is located just upstream of the mouth of the Stillwater River. The reach is a Partially Confined Braided (PCB) reach type, indicating valley wall influences and relatively extensive open gravel bars and small islands. The valley wall consists of erosion-resistant sandstone cliffs of the Hell Creek Formation. The river is confined by the valley wall to the south and by transportation infrastructure to the north. The river has been extremely dynamic in this reach; in some places the banks have migrated over a thousand feet since 1950.

Similar to other reaches in Region A, the overall footprint of the river channel has increased in size since 1950. In 1950, the channel footprint was 434 acres but by 2001 it had expanded to 570 acres.

About 13 percent of the banks in Reach A12 are armored, with the majority of that armor being rock riprap. Between 2001 and 2011, there was a gain of about 1,182 feet of rock riprap and 560 feet of flow deflectors in the reach. At least one flow deflector has been flanked on the right bank just upstream of the Stillwater confluence at RM 418.5. About two miles of transportation encroachments were mapped in Reach A12.

On side channel that is almost four thousand feet long at RM 421 was physically blocked in Reach A12 since 1950. More recently, however, the river has migrated back into the side channel such that the majority of it is now active.

Land use in Reach A12 is predominantly agricultural, although there are several hundred acres of exurban development in the reach. Almost a thousand acres of land is under flood irrigation. A total of 293 acres of developed land are in the Channel Migration Zone. Almost all of that ground is in flood irrigation, although 14 acres are in exurban development and 16 acres are in transportation. About 6 percent of the CMZ is isolated by physical features.

Riparian mapping in Reach A12 shows a reduction in total acreage of open timber from 43 acres in 1950 to 23 acres in 2001.

Reach A12 was sampled as part of the avian study. The average species richness in Reach A12 was 7.6, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for all sites evaluated is 8. One bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC), the Dickscissel, was identified in the reach.

Since 1950, Reach A12 has lost all of its forest that would be considered at low risk of cowbird infestation due to its separation from agricultural infrastructure. In 1950, about 4 acres of forest per valley mile were identified as low risk and by 2001 that forest area had been reduced to zero.

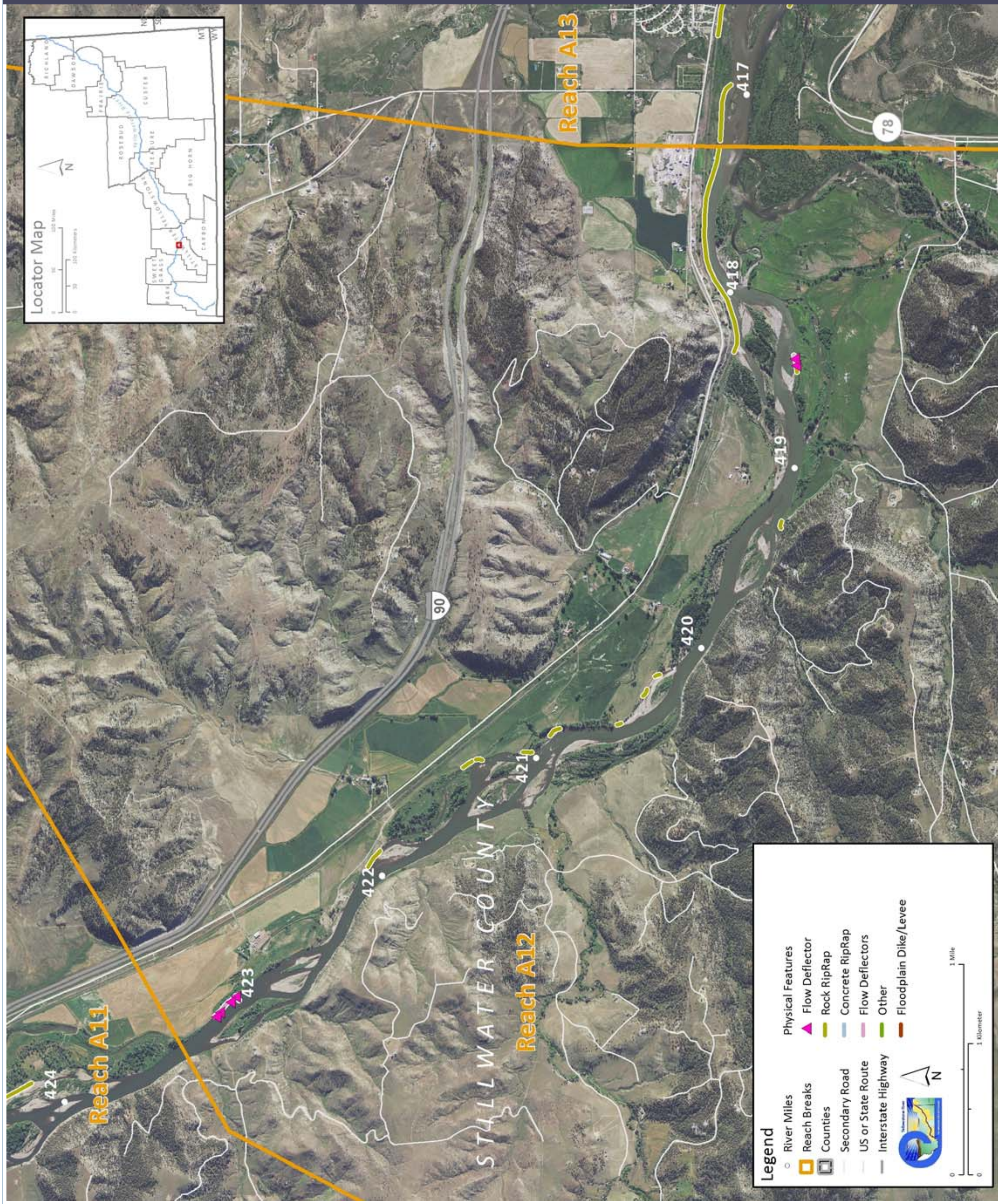
Reach A12 has approximately 3 acres of mapped Russian olive, which is most concentrated on the north side of the river on the banks of the main channel, side channels, and sloughs.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 14,400 cfs to 13,600 cfs, a drop of about 6 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,080 cfs to 1,690 cfs with human development, a reduction of 19 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A12 include:
•Recapture of previously blocked side channel
•Flanking of barbs

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A12 include:
•Bank armor removal at RM 418.5
•Russian olive removal (3 acres)

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	52.9	83.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	14,400	27,900	34,900	39,100	47,800	51,300	59,200	2,080	1,760
Regulated	13,600	27,000	34,100	38,300	47,200	50,800	58,900	1,690	1,680
% Change	-5.56%	-3.23%	-2.29%	-2.05%	-1.26%	-0.97%	-0.51%	-18.75%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	22-May-51	B/W	1:28,400	6192500	10600
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	9/2/96 - 9/10/96	B/W		6192500	2980
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2004	Merrick	14-May-04	Color	1:15,840	6192500	4520
2005	NAIP	07/27/2005	color	1-meter pixels	6192500	3540
2005	NAIP	07/15/2005	color	1-meter pixels	6192500	5000
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	USCOE	October 2012	color	1-ft pixel	6192500	2530
2011	NAIP	7/24/2011	Color	1-meter pixels	6192500	13100
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	6,133	9.5%	7,316	11.4%	1,182
	Flow Deflectors	125	0.2%	262	0.4%	137
	Between Flow Deflectors	173	0.3%	593	0.9%	419
	Feature Type Totals	**6,431**	**10.0%**	**8,170**	**12.7%**	**1,739**
Floodplain Control						
	Transportation Encroachment	10,430	16.2%	10,430	16.2%	0
	Feature Type Totals	**10,430**	**16.2%**	**10,430**	**16.2%**	**0**
	Reach Totals	**16,862**	**26.2%**	**18,601**	**28.9%**	**1,739**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	0	177	0	0	0	0	0	0
Rock RipRap	830	0	0	0	0	5,304	0	0
Totals	**830**	**177**	**0**	**0**	**0**	**5,304**	**0**	**0**

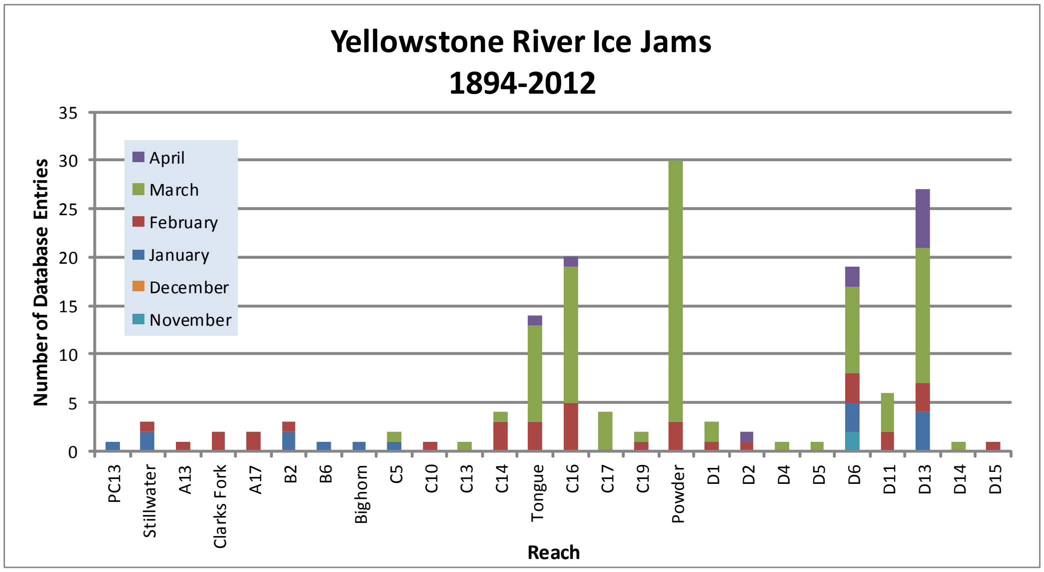
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

Feature Class	Feature Type	Sum of Feature Length (ft) 1950	1976	1995	2001	2004	2005
Stream Stabilization							
	Rock RipRap	5,040	5,865	7,945	8,103	8,103	8,103
	Flow Deflector	0	1,697	1,697	1,734	2,093	2,093
	Totals	**5,040**	**7,561**	**9,642**	**9,837**	**10,196**	**10,196**
Transportation Encroachment							
	Railroad	8,100	8,100	8,100	8,100	8,100	8,100
	County Road	2,487	2,487	2,487	2,487	2,487	2,487
	Totals	**10,587**	**10,587**	**10,587**	**10,587**	**10,587**	**10,587**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	31,599	26,114	1.83	1950 to 1976:	-0.65%
1976	31,053	25,294	1.81	1976 to 1995:	-14.17%
1995	31,950	17,810	1.56	1995 to 2001:	14.15%
2001	32,166	25,017	1.78	1950 to 2001:	-2.66%
Change 1950 - 2001	**566**	**-1,096**	**-0.05**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	3,771

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	487		656	
Total Floodplain Area (Ac)	487		670	
Total Isolated (Ac)	**0**	**0.0%**	**14**	**14.0%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	19	0	0	**19**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
382	763	1,417	93	7%	11	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Railroad	61	4.2%
	Irrigated	16	1.1%
Flow Deflectors			
	Irrigated	15	1.0%
	Totals	**91**	**6.4%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
263.8	0.0	0.0	13.5	15.5

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	60	71	74	79	1.5%	1.8%	1.8%	2.0%
	Totals	**61**	**71**	**74**	**79**	**1.5%**	**1.8%**	**1.8%**	**2.0%**
Agricultural Land									
	Non-Irrigated	2,130	2,158	2,039	1,991	53.1%	53.8%	50.8%	49.6%
	Irrigated	1,201	1,087	1,035	999	29.9%	27.1%	25.8%	24.9%
	Totals	**3,331**	**3,245**	**3,073**	**2,990**	**83.0%**	**80.9%**	**76.6%**	**74.5%**
Channel									
	Channel	543	575	668	703	13.5%	14.3%	16.6%	17.5%
	Totals	**543**	**575**	**668**	**703**	**13.5%**	**14.3%**	**16.6%**	**17.5%**
ExUrban									
	ExUrban Other	6	9	32	40	0.2%	0.2%	0.8%	1.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	16	68	103	0.0%	0.4%	1.7%	2.6%
	Totals	**6**	**25**	**100**	**143**	**0.2%**	**0.6%**	**2.5%**	**3.6%**
Transportation									
	Public Road	39	39	39	39	1.0%	1.0%	1.0%	1.0%
	Interstate	0	26	26	26	0.0%	0.6%	0.6%	0.6%
	Railroad	31	31	31	31	0.8%	0.8%	0.8%	0.8%
	Totals	**70**	**96**	**96**	**96**	**1.7%**	**2.4%**	**2.4%**	**2.4%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	1,201	1,087	1,035	980	36.1%	33.5%	33.7%	33.0%	-2.6%	0.2%	-0.7%	-3.1%
	Totals	**1,201**	**1,087**	**1,035**	**981**	**36.1%**	**33.5%**	**33.7%**	**33.0%**	**-2.6%**	**0.2%**	**-0.7%**	**-3.1%**

Non-Irrigated												
Multi-Use	1,774	1,858	1,903	1,821	53.3%	57.3%	61.9%	61.3%	4.0%	4.7%	-0.7%	8.0%
Hay/Pasture	356	300	136	170	10.7%	9.3%	4.4%	5.7%	-1.4%	-4.8%	1.3%	-5.0%
Totals	**2,130**	**2,158**	**2,039**	**1,991**	**63.9%**	**66.5%**	**66.3%**	**67.0%**	**2.6%**	**-0.2%**	**0.7%**	**3.1%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.6	0.4	0.6	2.1	0.2	0.9	3.0	5.5	3.1
Max	11.1	18.1	21.3	55.6	58.1	58.9	15.6	10.5	7.9
Average	4.7	4.1	4.9	12.7	10.2	9.7	8.6	7.2	5.8
Sum	89.9	86.6	63.5	202.5	203.3	223.8	42.8	21.6	23.0

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	117.2
Channel to Riparian (acres)	104.4
Riparian Encroachment (acres)	**-12.7**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	0.0
1950s Floodplain Mapped as 2011 Channel (Ac)	0.1
Total Recruitment (1950s to 2011)(Ac)	**0.1**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	5.7	55.5	69.1	0.0	**130.4**
Acres/Valley Mile	1.0	9.9	12.3	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	2.89	0.23%	1.24	0.02	1.30	0.55

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern Potential Species of Concern

Reach	Region	Species	Reach	Region	Species	Reach	Region	Species	Reach	Region	Species
✓	✓	American Robin		✓	Chipping Sparrow			Killdeer	✓	✓	Song Sparrow
	✓	American Crow		✓	Clay-collared Sparrow			Lark Bunting			Spotted Sandpiper
✓	✓	American Goldfinch		✓	Cliff Swallow		✓	Lark Sparrow		✓	Spotted Towhee
		American Kestrel	✓	✓	Common Grackle		✓	Lazuli Bunting			Sharp-shinned Hawk
✓	✓	American Redstart			Common Merganser	✓	✓	Least Flycatcher	✓	✓	Swainson's Thrush
		Bald Eagle			Common Nighthawk			Mallard			Sandhill Crane
		Baltimore Oriole			Common Raven		✓	Mountain Bluebird		✓	Tree Swallow
	✓	Barn Swallow		✓	Common Yellowthroat		✓	Mourning Dove			Turkey Vulture
		Belted Kingfisher			Cooper's Hawk	✓	✓	Northern Flicker			Upland Sandpiper
		Black-billed Cuckoo	✓	✓	Dickcissel			Orchard Oriole	✓	✓	Vesper Sparrow
	✓	Black-billed Magpie	✓	✓	Downy Woodpecker			Osprey		✓	Violet-green Swallow
✓	✓	Black-capped Chickadee			Eastern Bluebird		✓	Ovenbird	✓	✓	Warbling Vireo
	✓	Black-and-white Warbler		✓	Eastern Kingbird			Plumbeous Vireo		✓	Western Kingbird
✓	✓	Black-headed Grosbeak			Eurasian Collared-dove			Red-headed Woodpecker		✓	Western Meadowlark
	✓	Blue Jay		✓	European Starling		✓	Red-naped Sapsucker	✓	✓	Western Wood-pewee
	✓	Bobolink		✓	Field Sparrow			Red Crossbill		✓	White-breasted Nuthatch
	✓	Brewer's Blackbird			Franklin's Gull			Ring-necked Pheasant		✓	White-throated Swift
✓	✓	Brown-headed Cowbird			Grasshopper Sparrow			Red-tailed hawk			Wild Turkey
		Brown Creeper	✓	✓	Gray Catbird			Rock Dove			Wood Duck
	✓	Brown Thrasher			Great Blue Heron	✓	✓	Red-winged Blackbird			Yellow-bellied Sapsucker
✓	✓	Bullock's Oriole			Great Horned Owl	✓	✓	Red-eyed Vireo			Yellow-billed Cuckoo
		Canada Goose	✓	✓	Hairy Woodpecker			Red-breasted Grosbeak		✓	Yellow-breasted Chat
✓	✓	Cedar Waxwing			House Finch			Say's Phoebe		✓	Yellow-headed Blackbird
	✓	Chimney Swift	✓	✓	House Wren		✓	Savannah Sparrow	✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Stillwater	**Upstream River Mile**	417.3
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	413.7
General Location	Columbus	**Length**	3.60 mi (5.79 km)
General Comments	Example of an impacted valley bottom crossover area		

Narrative Summary

Reach A13 is 3.6 miles long and is located at Columbus. The reach is a Partially Confined Anabranching (PCA) reach type, indicating some valley wall influence and relatively extensive forested islands. Reach A13 marks an abrupt widening in the river valley as the erosion resistant sandstone cliffs of the Hell Creek Formation transition downstream into the more erodible Bearpaw Shale. The reach is urbanized with most development concentrated on the north side of the river. Migration rates since 1950 have been moderate in this reach largely due to extensive bank armoring.

Similar to other reaches in Region A, the overall footprint of the river channel has increased in size since 1950. In 1950, the channel footprint was 258 acres but by 2001 it had expanded to 327 acres. This was accompanied by a net loss of about 40 acres of riparian area to channel during that same timeframe.

About 28 percent of the banks in Reach A13 are armored, with the majority of that armor being rock riprap. Reach A13 has almost 3,000 feet of concrete riprap, reflecting an abrupt increase in the use of concrete as armor relative to upstream. The concrete is on the north bank of the river just upstream of the Columbus Bridge. Between 2001 and 2011, there was a gain of about 2,800 feet of rock riprap in the reach; most of this was on the north side of the river adjacent to town.

Land use in Reach A13 is predominantly agricultural, although there are over 600 acres of exurban/exurban development within the mapping footprint. Approximately one half of the agricultural land is in flood irrigation (600 acres). No other types of irrigation were mapped in the reach. A total of 133 acres of developed land are in the Channel Migration Zone, and about half of that is in urban/exurban development. About 13 percent of the CMZ is isolated by physical features, most of which is armor protecting the railroad in Columbus.

About 18 percent of the historic 100-year floodplain has become isolated from the river due primarily to the downstream shadow caused by the Columbus Bridge embankment on the north side of the river.

There is one pipeline crossing in Reach A13, a natural gas crossing called the Lake Basin-Absarokee Line owned by NW energy. The pipeline crosses the river at RM 417.

One ice jam has been recorded in this reach. On February 6, 1996, an ice jam break-up was reported to cause local flooding.

There are corrals that are part of an animal handling facility in the reach, north of the river at RM 414.

Riparian mapping in Reach A13 shows a reduction of about 50 acres of closed timber in the reach since 1950.

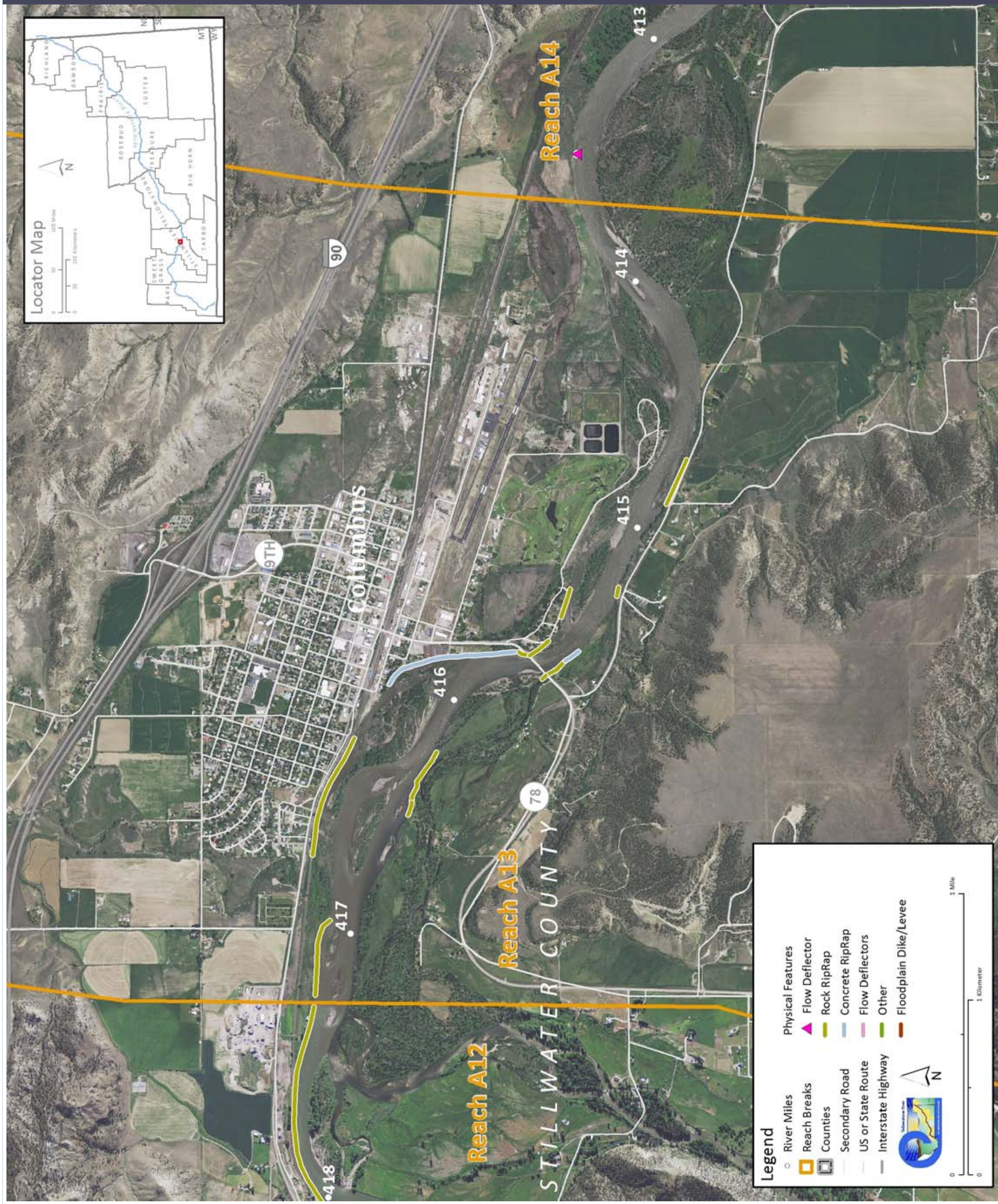
Reach A13 has approximately 5 acres of mapped Russian olive, which is spread out both within the riparian corridor and through the town of Columbus. There are also over 100 acres of mapped wetland in the each, most of which is emergent marshes and wet meadows.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 14,400 cfs to 13,600 cfs, a drop of about 6 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,270 cfs to 1,760 cfs with human development, a reduction of 22 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A13 include:
•A jump in the use of concrete armor relative to upstream
•Armoring associated with urbanization
•Urban/Exurban development in CMZ

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A13 include:
•CMZ management at Columbus due to high level of encroachment
•Nutrient management at corrals at RM 414
•Bank Stabilization Recommended Practices due to extent of armoring in reach (28 percent)
•Russian olive removal (5 acres)
•Pipeline management (natural gas) for main river crossing at RM 417
•Wetland restoration/management due to extent of mapped wetland (110 acres)

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	49.3	89.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	16,200	31,000	38,600	43,300	52,700	56,600	65,200	2,270	1,760
Regulated	15,100	29,800	37,500	42,300	51,900	55,900	64,800	1,760	1,680
% Change	-6.79%	-3.87%	-2.85%	-2.31%	-1.52%	-1.24%	-0.61%	-22.47%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	22-May-51	B/W	1:28,400	6192500	10600
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	9/10/96 - 8/28/97	B/W		6192500	4430
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2004	Merrick	14-May-04	Color	1:15,840	6192500	4520
2005	NAIP	07/15/2005	color	1-meter pixels	6192500	5000
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	USCOE	October 2012	color	1-ft pixel	6192500	2530
2011	NAIP	7/24/2011	Color	1-meter pixels	6192500	13100
2013	NAIP	06/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	5,092	13.4%	7,875	20.7%	2,783
	Concrete RipRap	2,837	7.5%	2,837	7.5%	0
	Feature Type Totals	**7,929**	**20.9%**	**10,712**	**28.2%**	**2,783**
	Reach Totals	**7,929**	**20.9%**	**10,712**	**28.2%**	**2,783**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	0	0	0	1,571	0	0	0	1,269
Rock RipRap	0	285	0	1,998	0	1,476	0	544
Totals	**0**	**285**	**0**	**3,569**	**0**	**1,476**	**0**	**1,814**

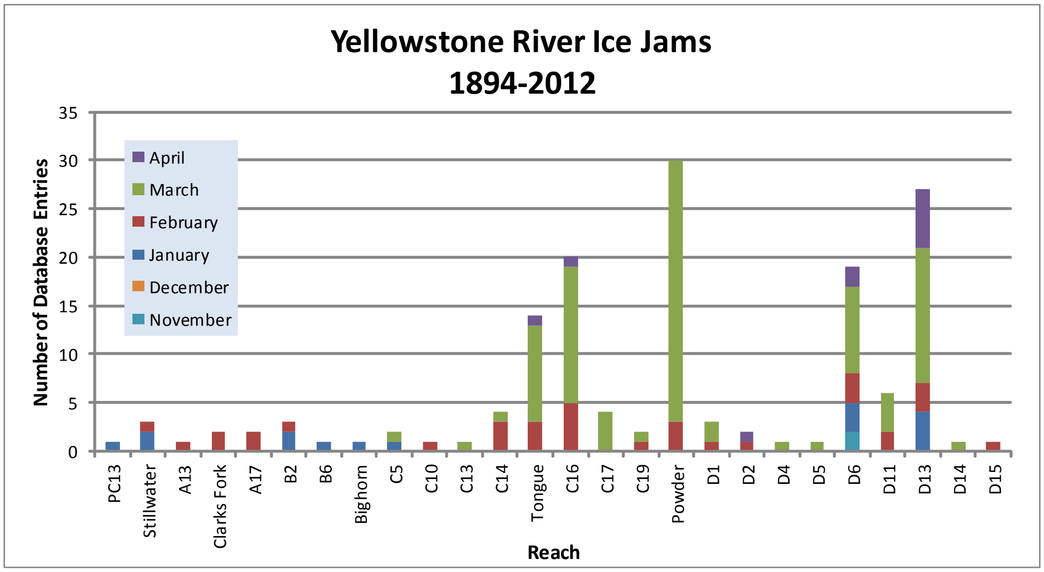
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

Feature Class	Feature Type	Sum of Feature Length (ft) 1950	1976	1995	2001	2004	2005
Other							
	Floodplain Dike/Levee	0	2,395	4,675	4,675	4,675	4,675
	Totals	**0**	**2,395**	**4,675**	**4,675**	**4,675**	**4,675**
Other Off Channel							
	Floodplain Dike/Levee	0	666	666	666	666	666
	Totals	**0**	**666**	**666**	**666**	**666**	**666**
Stream Stabilization							
	Rock RipRap	3,406	4,993	6,634	8,187	8,187	8,187
	Concrete RipRap	0	0	2,822	2,822	2,822	2,822
	Totals	**3,406**	**4,993**	**9,457**	**11,010**	**11,010**	**11,010**
Transportation Encroachment							
	Railroad	6,127	6,127	6,127	6,127	6,127	6,127
	County Road	7,931	5,756	5,756	5,756	5,756	5,756
	Bridge Approach	2,975	1,749	1,749	1,749	1,749	1,749
	Totals	**17,032**	**13,632**	**13,632**	**13,632**	**13,632**	**13,632**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
2/6/1996	Break-up	416	Flooding

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	19,288	17,765	1.92
1976	18,865	18,941	2.00
1995	18,891	20,378	2.08
2001	18,980	19,208	2.01
Change 1950 - 2001	**-308**	**1,443**	**0.09**

	% Change in Braiding
1950 to 1976:	4.32%
1976 to 1995:	3.73%
1995 to 2001:	-3.21%
1950 to 2001:	4.74%

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	72	18.3%		
Total Not Isolated (Ac)	321		403	
Total Floodplain Area (Ac)	393		414	
Total Isolated (Ac)	**72**	**18.3%**	**11**	**12.7%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	1	0	0	**1**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
172	343	654	108	17%	106	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Urban Other	19	2.5%
RipRap			
	Urban Commercial	20	2.7%
	Railroad	44	5.8%
	Non-Irrigated	7	0.9%
	Irrigated	10	1.3%
	Totals	**101**	**13.3%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
56.1	0.0	0.0	61.9	14.6

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	44	92	82	79	1.8%	3.7%	3.3%	3.2%
	Totals	**44**	**92**	**82**	**79**	**1.8%**	**3.7%**	**3.3%**	**3.2%**
Agricultural Land									
	Non-Irrigated	1,092	1,117	763	733	43.7%	44.7%	30.5%	29.3%
	Irrigated	686	520	581	599	27.5%	20.8%	23.2%	24.0%
	Totals	**1,778**	**1,637**	**1,344**	**1,332**	**71.2%**	**65.5%**	**53.8%**	**53.3%**
Channel									
	Channel	325	353	380	390	13.0%	14.1%	15.2%	15.6%
	Totals	**325**	**353**	**380**	**390**	**13.0%**	**14.1%**	**15.2%**	**15.6%**
ExUrban									
	ExUrban Other	1	19	19	128	0.1%	0.8%	0.8%	5.1%
	ExUrban Undeveloped	12	17	41	14	0.5%	0.7%	1.6%	0.6%
	ExUrban Industrial	0	0	9	58	0.0%	0.0%	0.4%	2.3%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	17	42	46	0.0%	0.7%	1.7%	1.8%
	Totals	**13**	**53**	**110**	**246**	**0.5%**	**2.1%**	**4.4%**	**9.8%**
Transportation									
	Public Road	50	48	48	48	2.0%	1.9%	1.9%	1.9%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	18	18	18	18	0.7%	0.7%	0.7%	0.7%
	Totals	**68**	**66**	**66**	**67**	**2.7%**	**2.6%**	**2.6%**	**2.7%**
Urban									
	Urban Other	10	9	107	9	0.4%	0.4%	4.3%	0.4%
	Urban Residential	103	113	138	153	4.1%	4.5%	5.5%	6.1%
	Urban Commercial	59	58	57	57	2.4%	2.3%	2.3%	2.3%
	Urban Undeveloped	9	4	16	4	0.4%	0.1%	0.6%	0.1%
	Urban Industrial	89	114	198	161	3.6%	4.6%	7.9%	6.5%
	Totals	**271**	**298**	**516**	**385**	**10.8%**	**11.9%**	**20.7%**	**15.4%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	41	41	0	0.0%	2.5%	3.0%	0.0%	2.5%	0.5%	-3.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	686	479	540	599	38.6%	29.3%	40.2%	45.0%	-9.3%	10.9%	4.8%	6.4%
	Totals	**686**	**520**	**581**	**599**	**38.6%**	**31.8%**	**43.2%**	**45.0%**	**-6.8%**	**11.4%**	**1.8%**	**6.4%**

Non-Irrigated

Multi-Use	804	710	621	578	45.2%	43.3%	46.2%	43.4%	-1.9%	2.9%	-2.9%	-1.9%
Hay/Pasture	288	407	142	155	16.2%	24.9%	10.6%	11.7%	8.7%	-14.3%	1.1%	-4.5%
Totals	**1,092**	**1,117**	**763**	**733**	**61.4%**	**68.2%**	**56.8%**	**55.0%**	**6.8%**	**-11.4%**	**-1.8%**	**-6.4%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.7	1.6	2.6	0.0	2.6	5.9	2.5	6.2	4.7
Max	22.3	9.7	15.1	85.9	100.0	102.3	20.6	34.0	4.7
Average	14.4	5.6	8.9	24.2	28.4	31.2	10.3	20.1	4.7
Sum	71.8	22.5	44.6	290.9	256.0	249.8	31.0	40.2	4.7

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	83.2
Channel to Riparian (acres)	44.6
Riparian Encroachment (acres)	**-38.6**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	18.1	75.8	16.2	0.0	**110.1**
Acres/Valley Mile	5.7	23.8	5.1	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	4.96	1.09%	8.78	0.30	0.90	0.41

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Stillwater	**Upstream River Mile**	413.7
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	405.9
General Location	Below Columbus	**Length**	7.80 mi (12.55 km)
General Comments	Valley bottom crossover		

Narrative Summary

Reach A14 is located in Stillwater County, just downstream of Columbus. The reach is a Partially Confined Anabranching (PCA) reach type, reflecting some valley while influence coupled with relatively extensive forested islands. The reach is 7.8 miles long, extending from RM 405.9 to RM 413.7. The partial geologic confinement within Reach A14 is created by interbedded sandstone and shale of the Cretaceous-age Judith River Formation that intermittently forms the active channel margin on either its right or left bank. The Parkman Sandstone, a massive cliff-forming unit within the Judith River Formation, forms cliffs against the channel that are commonly over 150 feet high.

Similar to other reaches in Region A, the overall footprint of the river channel has increased in size since 1950. In 1950, the channel footprint was 637 acres but by 2001 it had expanded to 728 acres. This was accompanied by a net loss of about 32 acres of riparian area to channel during that same timeframe.

Approximately 16 percent of the bankline in Reach A14 is armored, and the armor is almost entirely rock riprap, with a very short section of flow deflectors. The armor is located almost entirely on the northern corridor margin, where transportation infrastructure (mainly railroad) follows the edge of the valley.

Over three miles of side channels have been blocked in Reach A14, with about half of the blockages occurring prior to 1950 and half after. The losses occurred on two distinct channels, one at RM 410 on the south side of the corridor and one at RM 407 on the north side.

Land use in Reach A14 is almost entirely agricultural, with almost 260 acres mapped as agricultural infrastructure. This in part reflects corrals that are part of an animal handling facility on the north side of the river at RM 409. There are 1,300 acres under flood irrigation in the reach, and 144 acres in pivot. A total of 227 acres of developed land are in the Channel Migration Zone, most of that is in flood irrigation (215 acres). Less than 2 percent of the CMZ is isolated by physical features, all of which is behind the armored rail line on the north side of the river.

There is one major diversion in Reach A14; Cove Ditch diverts water from the north bank at RM 410.

Reach A14 was sampled as part of the avian study. The average species richness in Reach A14 was 7.9, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for all sites evaluated is 8. Riparian mapping in Reach A14 shows a reduction of about 100 acres of closed timber in the reach since 1950. Since 1950, Reach A14 has lost most of its forest that would be considered at low risk of cowbird infestation due to its separation from agricultural infrastructure. In 1950, about 10.5 acres of forest per valley mile were identified as low risk and by 2001 that forest area had been reduced to 0.5 acres per valley mile.

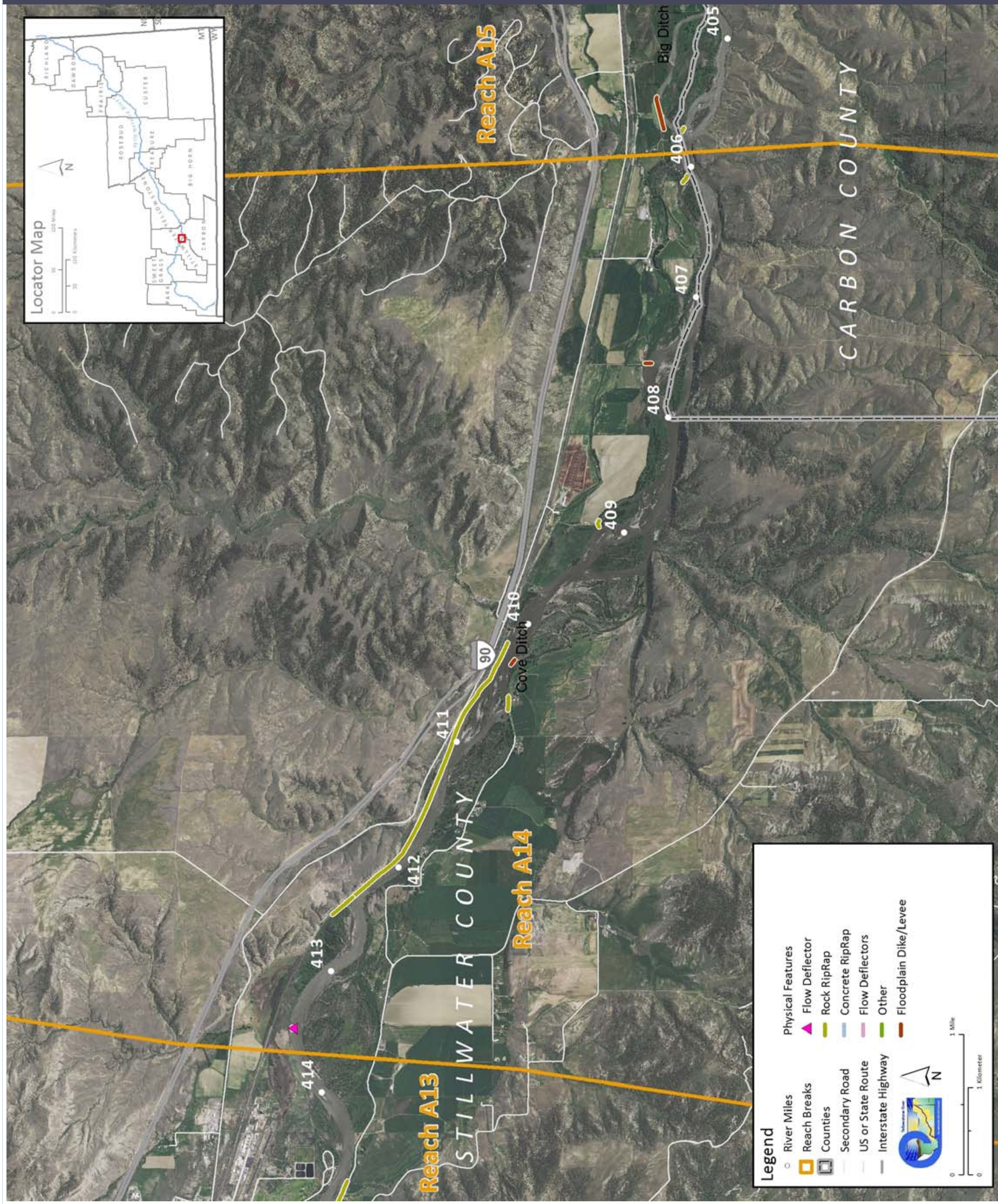
Reach A14 has approximately 2.5 acres of mapped Russian olive, which is concentrated along ditches and low riparian/wetland areas north of the river. There are also over 250 acres of mapped wetland in the each, most of which is emergent marshes and wet meadows. About 27 acres of emergent wetland have been isolated from the river corridor by the rail line at RM 413.5.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 16,200 cfs to 15,100 cfs, a drop of about 7 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,280 cfs to 1,770 cfs with human development, a reduction of 22 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A14 include:
•Isolation of large wetland area by rail line
•Over 3 miles of side channel blockages
•Large corrals that are part of an animal handling facility within 1,000 feet of the riverbank

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A14 include:
•Side channel restoration at RM 410 and RM 407
•Russian olive removal (2.5 acres)
•Nutrient management at corrals that are part of an animal handling facility at RM 409
•Irrigation diversion structure management at Cove Ditch Diversion
•Wetland management/restoration at large complex isolated from river by rail line at RM 413.5

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	41.5	92.9

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	16,200	31,000	38,600	43,300	52,700	56,600	65,200	2,280	1,760
Regulated	15,100	29,800	37,500	42,300	51,900	55,900	64,800	1,770	1,680
% Change	-6.79%	-3.87%	-2.85%	-2.31%	-1.52%	-1.24%	-0.61%	-22.37%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	22-May-51	B/W	1:28,400	6192500	10600
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	8/28/97 - 8/26/96 - 7/27/96	B/W		6192500	6960
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2004	Merrick	14-May-04	Color	1:15,840	6192500	4520
2005	NAIP	07/15/2005	color	1-meter pixels	6192500	5000
2005	NAIP	07/12/2005	color	1-meter pixels	6192500	5960
2009	NAIP	7/22/2009	Color	1-meter pixels	6192500	6990
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2009	NAIP	6/29/2009	Color	1-meter pixels	6192500	13900
2011	USCOE	October 2012	color	1-ft pixel	6192500	2530
2011	NAIP	7/24/2011	Color	1-meter pixels	6192500	13100
2013	NAIP	06/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	11,650	14.2%	13,458	16.4%	1,807
	Flow Deflectors	64	0.1%	64	0.1%	0
	Feature Type Totals	**11,714**	**14.3%**	**13,521**	**16.5%**	**1,807**
Other In Channel						
	Bedrock Control	676	0.8%	676	0.8%	0
	Feature Type Totals	**676**	**0.8%**	**676**	**0.8%**	**0**
Floodplain Control						
	Transportation Encroachment	1,605	2.0%	1,605	2.0%	0
	Floodplain Dike/Levee	230	0.3%	225	0.3%	-5
	Feature Type Totals	**1,835**	**2.2%**	**1,831**	**2.2%**	**-5**
	Reach Totals	**14,225**	**17.3%**	**16,028**	**19.5%**	**1,803**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	62	0	0	0	0	0	0	0
Rock RipRap	249	0	0	0	0	11,398	0	0
Totals	**312**	**0**	**0**	**0**	**0**	**11,398**	**0**	**0**

Bankline/Floodplain Inventory: Time Series

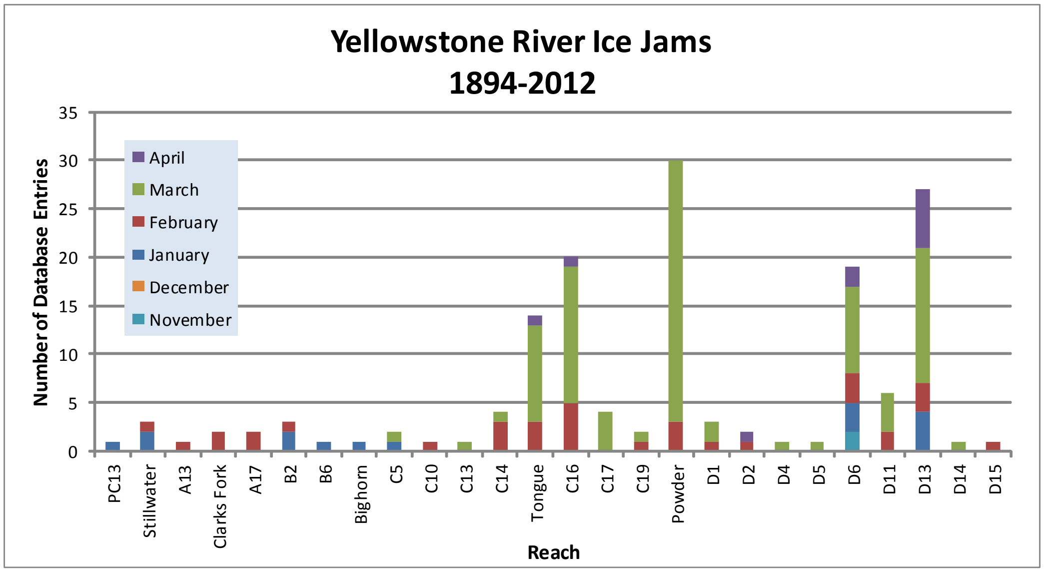
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	In Channel Diversion	0	207	207	207	207	207
	Floodplain Dike/Levee	6,820	6,820	6,820	6,820	6,820	6,820
	Totals	**6,820**	**7,027**	**7,027**	**7,027**	**7,027**	**7,027**
Other Off Channel							
	Floodplain Dike/Levee	0	258	258	471	471	471
	Floodplain Dike/Levee	2,576	2,576	2,576	2,866	2,866	2,866
	Totals	**2,576**	**2,834**	**2,834**	**3,337**	**3,337**	**3,337**
Stream Stabilization							
	Rock RipRap	13,555	13,555	14,157	14,157	14,157	14,157
	Flow Deflector	0	185	185	185	400	400

Totals	**13,555**	**13,740**	**14,341**	**14,341**	**14,557**	**14,557**
Transportation Encroachment						
Railroad	10,381	10,381	10,381	10,381	10,381	10,381
Other	10,900	10,900	10,900	10,900	10,900	10,900
County Road	1,729	1,729	1,729	1,729	1,729	1,729
Totals	**23,010**	**23,010**	**23,010**	**23,010**	**23,010**	**23,010**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	42,099	56,155	2.33	**1950 to 1976:**	-3.61%
1976	40,060	50,059	2.25	**1976 to 1995:**	-15.02%
1995	41,418	37,765	1.91	**1995 to 2001:**	1.51%
2001	41,087	38,652	1.94	**1950 to 2001:**	-16.84%
Change 1950 - 2001	**-1,012**	**-17,502**	**-0.39**		

Length of Side Channels Blocked

Pre-1950s (ft)	9,672
Post-1950s (ft)	9,176

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	838		997	
Total Floodplain Area (Ac)	838		1037	
Total Isolated (Ac)	**0**	**0.0%**	**41**	**13.1%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	12	0	0	**12**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as “Restricted Migration Areas” (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as “Avulsion Potential Zones”.

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
293	587	1,671	27	2%	181	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Railroad	26	1.4%
	Totals	**26**	**1.4%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
215.4	0.0	0.0	0.0	11.4

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	74	112	249	259	1.3%	1.9%	4.3%	4.4%
	Totals	**74**	**112**	**249**	**259**	**1.3%**	**1.9%**	**4.3%**	**4.4%**
Agricultural Land									
	Non-Irrigated	3,052	2,969	3,002	2,980	52.2%	50.7%	51.3%	50.9%
	Irrigated	1,664	1,644	1,467	1,464	28.4%	28.1%	25.1%	25.0%
	Totals	**4,716**	**4,613**	**4,470**	**4,444**	**80.6%**	**78.8%**	**76.4%**	**75.9%**
Channel									
	Channel	973	929	934	962	16.6%	15.9%	16.0%	16.4%
	Totals	**973**	**929**	**934**	**962**	**16.6%**	**15.9%**	**16.0%**	**16.4%**
ExUrban									
	ExUrban Other	0	12	12	0	0.0%	0.2%	0.2%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**12**	**12**	**0**	**0.0%**	**0.2%**	**0.2%**	**0.0%**
Transportation									
	Public Road	53	55	55	55	0.9%	0.9%	0.9%	0.9%
	Interstate	0	96	96	96	0.0%	1.6%	1.6%	1.6%
	Railroad	37	37	37	37	0.6%	0.6%	0.6%	0.6%
	Totals	**90**	**188**	**189**	**189**	**1.5%**	**3.2%**	**3.2%**	**3.2%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	144	0.0%	0.0%	0.0%	3.2%	0.0%	0.0%	3.2%	3.2%
	Flood	1,664	1,644	1,467	1,320	35.3%	35.6%	32.8%	29.7%	0.4%	-2.8%	-3.1%	-5.6%
	Totals	**1,664**	**1,644**	**1,467**	**1,464**	**35.3%**	**35.6%**	**32.8%**	**32.9%**	**0.4%**	**-2.8%**	**0.1%**	**-2.3%**

Non-Irrigated													
Multi-Use	2,649	2,532	2,599	2,532	56.2%	54.9%	58.1%	57.0%	-1.3%	3.3%	-1.2%	0.8%
Hay/Pasture	403	436	403	448	8.6%	9.5%	9.0%	10.1%	0.9%	-0.4%	1.1%	1.5%
Totals	**3,052**	**2,969**	**3,002**	**2,980**	**64.7%**	**64.4%**	**67.2%**	**67.1%**	**-0.4%**	**2.8%**	**-0.1%**	**2.3%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	1.2	0.2	1.3	1.3	0.5	0.9	0.4	1.6	0.7
Max	4.8	10.0	20.9	146.2	107.9	137.3	33.2	114.5	35.7
Average	3.0	2.4	4.9	22.1	15.6	20.3	11.8	25.9	15.9
Sum	6.0	24.3	44.2	729.0	563.0	629.8	106.2	181.0	111.0

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	182.5
Channel to Riparian (acres)	150.7
Riparian Encroachment (acres)	**-31.8**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	0.0
1950s Floodplain Mapped as 2011 Channel (Ac)	2.5
Total Recruitment (1950s to 2011)(Ac)	**2.5**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	14.4	211.3	57.6	0.0	**283.3**
Acres/Valley Mile	2.0	29.3	8.0	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	2.55	0.12%	1.00	0.00	0.25	0.10

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern Potential Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
✓	✓	American Robin	✓	✓	Chipping Sparrow			Killdeer	✓	✓	Song Sparrow
✓	✓	American Crow		✓	Clay-collared Sparrow			Lark Bunting			Spotted Sandpiper
✓	✓	American Goldfinch		✓	Cliff Swallow		✓	Lark Sparrow	✓	✓	Spotted Towhee
		American Kestrel	✓	✓	Common Grackle	✓	✓	Lazuli Bunting			Sharp-shinned Hawk
✓	✓	American Redstart			Common Merganser	✓	✓	Least Flycatcher	✓	✓	Swainson's Thrush
		Bald Eagle			Common Nighthawk			Mallard			Sandhill Crane
✓	✓	Baltimore Oriole			Common Raven		✓	Mountain Bluebird	✓	✓	Tree Swallow
	✓	Barn Swallow	✓	✓	Common Yellowthroat	✓	✓	Mourning Dove			Turkey Vulture
		Belted Kingfisher			Cooper's Hawk	✓	✓	Northern Flicker			Upland Sandpiper
		Black-billed Cuckoo		✓	Dickcissel			Orchard Oriole		✓	Vesper Sparrow
✓	✓	Black-billed Magpie	✓	✓	Downy Woodpecker			Osprey	✓	✓	Violet-green Swallow
✓	✓	Black-capped Chickadee			Eastern Bluebird		✓	Ovenbird	✓	✓	Warbling Vireo
	✓	Black-and-white Warbler	✓	✓	Eastern Kingbird			Plumbeous Vireo		✓	Western Kingbird
✓	✓	Black-headed Grosbeak			Eurasian Collared-dove			Red-headed Woodpecker		✓	Western Meadowlark
	✓	Blue Jay	✓	✓	European Starling		✓	Red-naped Sapsucker	✓	✓	Western Wood-pewee
	✓	Bobolink		✓	Field Sparrow			Red Crossbill	✓	✓	White-breasted Nuthatch
✓	✓	Brewer's Blackbird			Franklin's Gull			Ring-necked Pheasant	✓	✓	White-throated Swift
✓	✓	Brown-headed Cowbird			Grasshopper Sparrow			Red-tailed hawk			Wild Turkey
		Brown Creeper	✓	✓	Gray Catbird			Rock Dove			Wood Duck
	✓	Brown Thrasher			Great Blue Heron	✓	✓	Red-winged Blackbird			Yellow-bellied Sapsucker
✓	✓	Bullock's Oriole			Great Horned Owl		✓	Red-eyed Vireo			Yellow-billed Cuckoo
		Canada Goose	✓	✓	Hairy Woodpecker			Red-breasted Grosbeak	✓	✓	Yellow-breasted Chat
✓	✓	Cedar Waxwing			House Finch			Say's Phoebe		✓	Yellow-headed Blackbird
	✓	Chimney Swift	✓	✓	House Wren		✓	Savannah Sparrow	✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Stillwater	**Upstream River Mile**	405.9
Classification	PCB: Partially confined braided	**Downstream River Mile**	400
General Location	Follows Stillwater/Carbon County line	**Length**	5.90 mi (9.50 km)
General Comments	Follows Stillwater/Carbon County line		

Narrative Summary

Reach A15 is located in Stillwater County between Columbus and Park City. The reach is a Partially Confined Braided (PCB) reach type, reflecting some valley wall influence coupled with relatively extensive open gravel bars and low flow channels. The reach is 5.9 miles long. The partial geologic confinement within Reach A15 is created by interbedded sandstone and shale of the Cretaceous-age Judith River Formation that intermittently forms the active channel margin on its right bank. The Parkman Sandstone, a massive cliff-forming unit within the Judith River Formation, forms cliffs against the channel that are commonly over 150 feet high.

Approximately 8 percent of the bankline in Reach A15 is armored, and the armor is almost entirely rock riprap, with a very short section of concrete armor. The armor is entirely located on the north bank of the river, across from the bluffs to the south.

Although no side channels have been mapped as blocked in the reach, the total anabranching channel length has dropped from 6.2 miles in 1950 to 4.2 miles in 2001.

Land use in Reach A15 is almost entirely agricultural, with over 200 acres mapped as agricultural infrastructure. This includes a large corral complex that is part of an animal handling facility on the north side of the river at RM 404. The corrals are behind a canal, but within a few hundred feet of the riverbank. There are 528 acres under flood irrigation in the reach, and 81 acres in pivot. A total of 119 acres of developed land are in the Channel Migration Zone, and all of that land is in flood irrigation. About 9 percent of the CMZ is isolated by physical features, all of which is behind armored canals associated with the Big Ditch Diversion, which diverts water from the north bank at RM 405.3. The Big Ditch Diversion structure fully spans a side channel of the river that is about 275 feet wide.

Riparian mapping in Reach A15 shows a reduction of about 60 acres of closed timber in the reach since 1950. Riparian recruitment rates have been relatively high; between 1950 and 2001 there were 200 acres of areas that recruited new riparian vegetation, and most of that was in old 1950s channels that were abandoned and became colonized. These abandoned channels also have high concentrations of Russian olive. Since 1950, Reach A15 has lost almost all of its forest that would be considered at low risk of cowbird infestation due to its separation from agricultural infrastructure. In 1950, about 20 acres of forest per valley mile were identified as low risk and by 2001 that forest area had been reduced to 1.

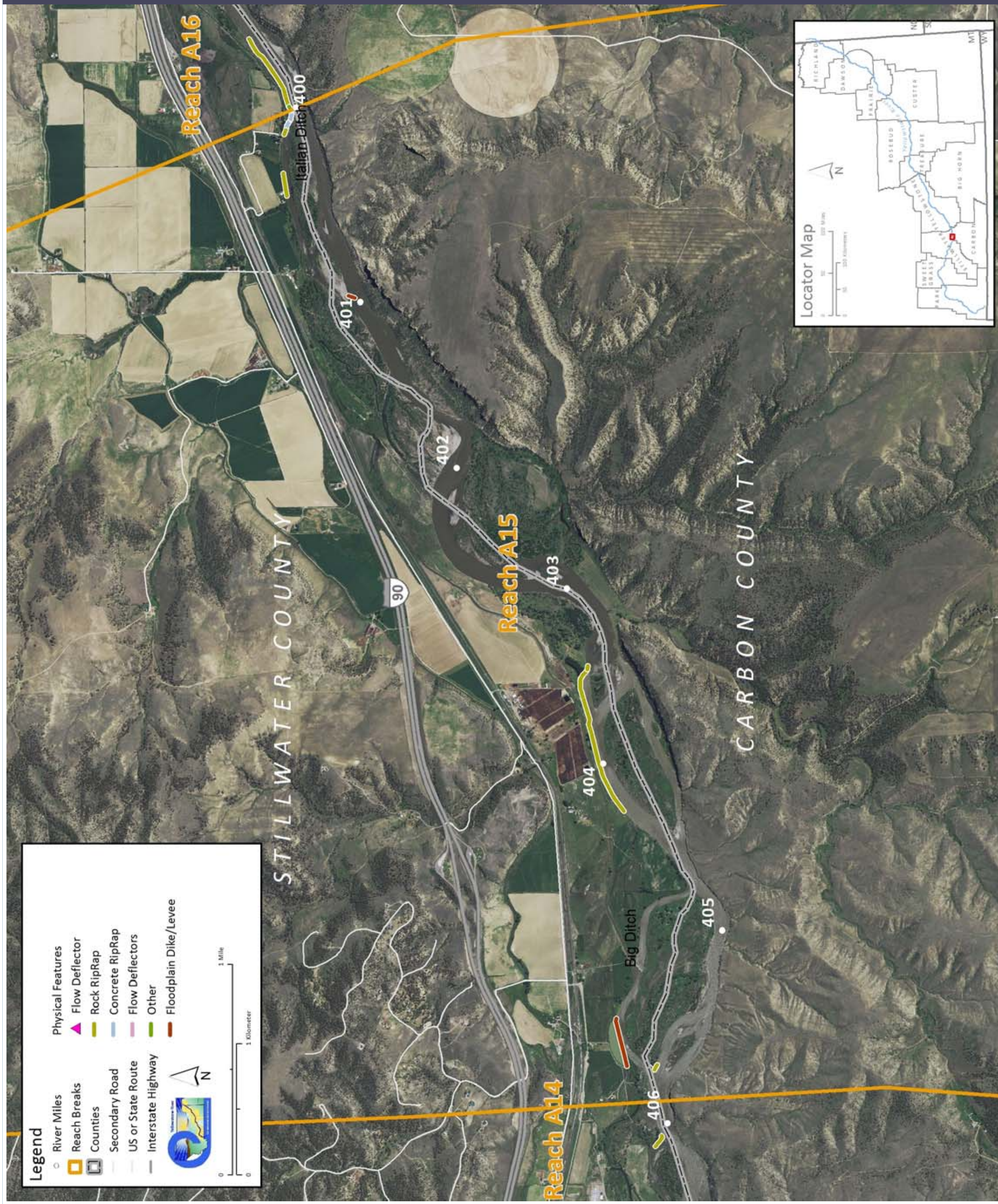
There are also over 150 acres of mapped wetland in the each, most of which is emergent marshes and wet meadows. Large expanses of emergent wetlands have developed in side channels that have been passively lost since 1950 (“passively” meaning not blocked but abandoned).

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 16,200 cfs to 15,100 cfs, a drop of about 7 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,286 cfs to 1,770 cfs with human development, a reduction of 23 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A15 include:
•Passive loss of 2 miles of side channel
•Russian olive colonization in abandoned side channels
•Emergent wetland development in abandoned side channels
•Large corrals that are part of an animal handling facility within 300 feet of the riverbank

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A15 include:
•Side channel restoration to reactivate 2 miles of passively lost channels
•Russian olive removal (1.2 acres)
•Nutrient management at corrals that are part of an animal handling facility at RM 404
•Consideration of watercraft passage at Big Ditch Diversion Structure
•Consideration of fish passage limitations at Big Ditch Diversion Structure
•Wetland management/restoration due to extent of mapped wetland (150 acres)

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	35.6	100.7

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	16,200	31,000	38,600	43,300	52,700	56,600	65,200	2,286	1,760
Regulated	15,100	29,800	37,500	42,300	51,900	55,900	64,800	1,770	1,680
% Change	-6.79%	-3.87%	-2.85%	-2.31%	-1.52%	-1.24%	-0.61%	-22.59%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	17-May-51	B/W	1:28,400	6192500	7430
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	27-Jul-96	B/W		6192500	6960
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2004	Merrick	14-May-04	Color	1:15,840	6192500	4520
2005	NAIP	07/12/2005	color	1-meter pixels	6192500	5960
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2009	NAIP	6/29/2009	Color	1-meter pixels	6192500	13900
2011	USCOE	October 2012	color	1-ft pixel	6192500	2530
2011	NAIP	7/24/2011	Color	1-meter pixels	6192500	13100
2013	NAIP	06/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	4,633	7.5%	4,667	7.5%	35
	Concrete RipRap	483	0.8%	483	0.8%	0
	Feature Type Totals	**5,116**	**8.2%**	**5,151**	**8.3%**	**35**
Other In Channel						
	Bedrock Control	219	0.4%	219	0.4%	0
	Feature Type Totals	**219**	**0.4%**	**219**	**0.4%**	**0**
Floodplain Control						
	Floodplain Dike/Levee	1,552	2.5%	1,384	2.2%	-168
	Feature Type Totals	**1,552**	**2.5%**	**1,384**	**2.2%**	**-168**
	Reach Totals	**6,887**	**11.1%**	**6,754**	**10.9%**	**-134**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	0	0	492	0	0	0	0	0
Rock RipRap	564	0	3,090	0	0	0	0	0
Totals	**564**	**0**	**3,582**	**0**	**0**	**0**	**0**	**0**

Bankline/Floodplain Inventory: Time Series

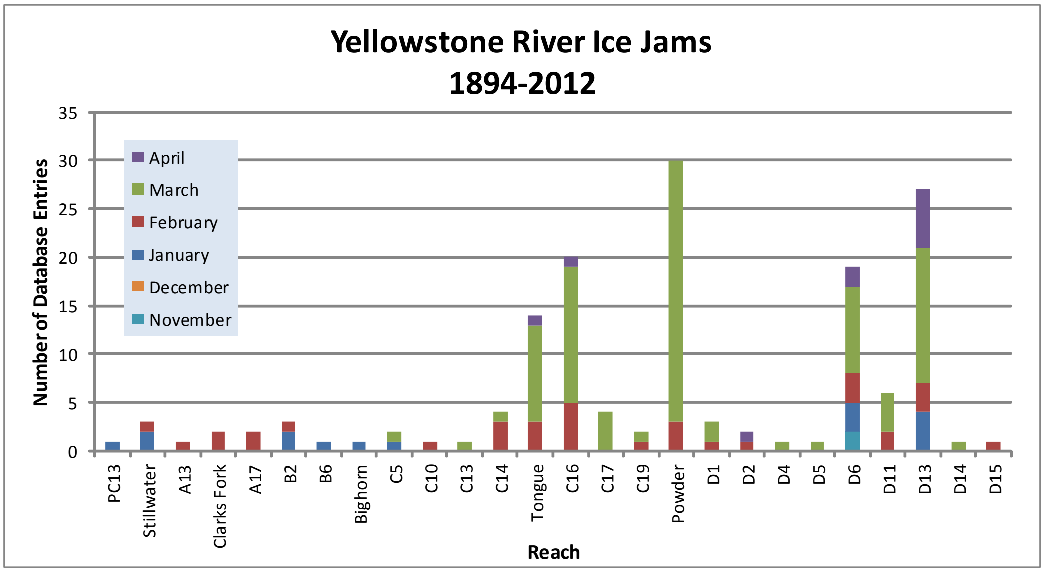
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	In Channel Diversion	473	473	473	642	642	642
	Floodplain Dike/Levee	5,561	6,313	6,313	6,313	6,313	6,313
	Totals	**6,035**	**6,786**	**6,786**	**6,955**	**6,955**	**6,955**
Other Off Channel							
	Floodplain Dike/Levee	1,287	1,833	1,833	1,833	1,833	1,833
	Floodplain Dike/Levee	0	3,926	3,926	3,926	3,926	3,926
	Totals	**1,287**	**5,759**	**5,759**	**5,759**	**5,759**	**5,759**
Stream Stabilization							
	Rock RipRap	2,363	5,630	6,605	6,605	7,003	7,003
	Concrete RipRap	449	449	449	449	449	449
	Totals	**2,812**	**6,079**	**7,054**	**7,054**	**7,452**	**7,452**

Transportation Encroachment						
Railroad	1,031	1,031	1,031	1,031	1,031	1,031
Totals	**1,031**	**1,031**	**1,031**	**1,031**	**1,031**	**1,031**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	29,740	32,759	2.10	1950 to 1976:	-18.33%
1976	30,410	21,783	1.72	1976 to 1995:	9.98%
1995	30,548	27,113	1.89	1995 to 2001:	-9.20%
2001	31,077	22,185	1.71	1950 to 2001:	-18.45%
Change 1950 - 2001	**1,337**	**-10,573**	**-0.39**		

Length of Side Channels Blocked

Pre-1950s (ft)	1,617
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	507		595	
Total Floodplain Area (Ac)	507		622	
Total Isolated (Ac)	**0**	**0.0%**	**27**	**24.5%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	1	0	0	**1**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
343	686	1,371	122	9%	97	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Other Infrastructure	7	0.5%
	Irrigated	11	0.7%
	Canal	75	5.1%
Dike/Levee			
	Irrigated	30	2.0%
	Totals	**122**	**8.3%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
118.7	0.0	0.0	0.0	0.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	62	57	57	57	1.7%	1.6%	1.6%	1.6%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	35	132	154	156	1.0%	3.6%	4.2%	4.3%
	Totals	**97**	**189**	**211**	**213**	**2.6%**	**5.1%**	**5.8%**	**5.8%**
Agricultural Land									
	Non-Irrigated	1,814	1,891	1,917	1,925	49.4%	51.5%	52.2%	52.5%
	Irrigated	925	696	639	608	25.2%	19.0%	17.4%	16.6%
	Totals	**2,739**	**2,587**	**2,556**	**2,534**	**74.6%**	**70.5%**	**69.6%**	**69.0%**
Channel									
	Channel	776	752	757	777	21.1%	20.5%	20.6%	21.2%
	Totals	**776**	**752**	**757**	**777**	**21.1%**	**20.5%**	**20.6%**	**21.2%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	2	2	0.0%	0.0%	0.1%	0.1%
	Totals	**0**	**0**	**2**	**2**	**0.0%**	**0.0%**	**0.1%**	**0.1%**
Transportation									
	Public Road	29	35	37	37	0.8%	1.0%	1.0%	1.0%
	Interstate	0	78	78	78	0.0%	2.1%	2.1%	2.1%
	Railroad	30	30	30	30	0.8%	0.8%	0.8%	0.8%
	Totals	**59**	**143**	**145**	**145**	**1.6%**	**3.9%**	**3.9%**	**3.9%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	1	81	0.0%	0.0%	0.0%	3.2%	0.0%	0.0%	3.1%	3.2%
	Flood	925	696	638	528	33.8%	26.9%	25.0%	20.8%	-6.9%	-2.0%	-4.1%	-12.9%
	Totals	**925**	**696**	**639**	**608**	**33.8%**	**26.9%**	**25.0%**	**24.0%**	**-6.9%**	**-1.9%**	**-1.0%**	**-9.8%**

Non-Irrigated												
Multi-Use	1,664	1,744	1,809	1,788	60.7%	67.4%	70.8%	70.6%	6.7%	3.3%	-0.2%	9.8%
Hay/Pasture	150	146	108	137	5.5%	5.7%	4.2%	5.4%	0.2%	-1.4%	1.2%	-0.1%
Totals	**1,814**	**1,891**	**1,917**	**1,925**	**66.2%**	**73.1%**	**75.0%**	**76.0%**	**6.9%**	**1.9%**	**1.0%**	**9.8%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.0	0.3	0.4	1.0	1.3	1.6	2.1	13.1	9.8
Max	80.3	32.2	65.3	105.0	137.7	170.7	12.2	50.0	73.0
Average	10.0	5.5	11.1	23.2	29.9	53.5	7.0	25.1	36.1
Sum	110.2	49.2	88.8	487.8	358.9	427.9	21.1	100.5	108.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	115.8
Channel to Riparian (acres)	120.5
Riparian Encroachment (acres)	**4.7**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	123.2
1950s Floodplain Mapped as 2011 Channel (Ac)	76.0
Total Recruitment (1950s to 2011)(Ac)	**199.2**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	10.4	131.1	27.4	0.0	**168.9**
Acres/Valley Mile	2.0	25.4	5.3	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	1.24	0.09%	0.16	0.04	0.48	0.14

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	107.7	57.2	7.6%
Rip Rap Bottom	25.0	24.6	3.3%
Bluff Pool	99.0	83.6	11.0%
Secondary Channel	78.4	57.8	7.6%
Secondary Channel (Seasonal)	67.2	32.3	4.3%
Channel Crossover	129.6	96.2	12.7%
Point Bar		43.5	5.7%
Side Bar		24.9	3.3%
Mid-channel Bar		23.9	3.2%
Island	249.9	250.7	33.1%
Dry Channel		62.1	8.2%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Stillwater	**Upstream River Mile**	400
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	392.4
General Location	Park City	**Length**	7.60 mi (12.23 km)

General Comments Near Park City, Reach A16 provides an example of a reach that supports numerous irrigation point features that appear to have a minimal effect on the stream corridor

Narrative Summary

Reach A16 is 7.6 miles long and is located just south of Park City. The reach is a Partially Confined Anabranching reach type, indicating some valley wall influences as well as relatively extensive forested islands. The partial geologic confinement within Reach A16 is created by interbedded sandstone and shale. In addition, both low and high alluvial terraces intermittently form the active river corridor margin.

Approximately 9 percent of the bankline in Reach A16 is armored, and the armor is almost entirely rock riprap, some short sections of concrete armor and flow deflectors. The armor is located almost entirely on the northern corridor margin, against terrace margins. Its use is split evenly between protecting agricultural and exurban residential land uses. On the upstream end of the reach, rock armor protects the Italian Ditch Diversion and Canal, which divert water on the north bank of the river at RM 400. Over four miles of floodplain dikes have been mapped in the reach, most of which follow ditches on the north floodplain.

Although there is no evidence that side channels have been intentionally blocked off in Reach A16, there has still been a net loss of over a mile of side channel since 1950. Similar to most reaches in Region A, the loss of side channels has been accompanied by an overall increase in the total channel footprint; since 1950, the bankfull channel area of Reach A16 has increased by 40 acres.

Land use in Reach A16 is almost entirely agricultural, although there are almost 300 acres of urban/exurban development in the mapping footprint. There are corrals that are part of an animal handling facility within 1,000 feet of an abandoned river swale at RM 395. Over a thousand acres under of ground in Reach A16 are under flood irrigation, and about 11 are in pivot. About 150 acres of developed land are in the Channel Migration Zone, and almost 40 acres of that is in urban/exurban development. About 6 percent of the total CMZ is restricted by bank armor and dikes.

There is one pipeline crossing in Reach A16. It crosses under the river at RM 396.7 and consists of a 24 inch crude oil pipeline that is owned by Kinder Morgan Pipelines. This pipeline was horizontally drilled during its installation.

Reach A16 was sampled as part of the avian study. The average species richness in Reach A16 was 8.5, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for all sites evaluated is 8. An average of one cowbird was observed during the field sampling visits. Reach A16 has lost about one half of its riparian forest considered at low risk of cowbird parasitism since 1950. At that time, there were about 12 acres of forest per valley mile considered to be isolated enough from agricultural infrastructure and urban/exurban development to be considered at low risk. By 2011, about 6.6 acres considered low risk remained.

There are over 250 acres of mapped wetland in the reach, with most of that emergent marshes wand wet meadows. Many of these wetland areas occupy old river swales on the floodplain north of the river, or abandoned channels in the active corridor.

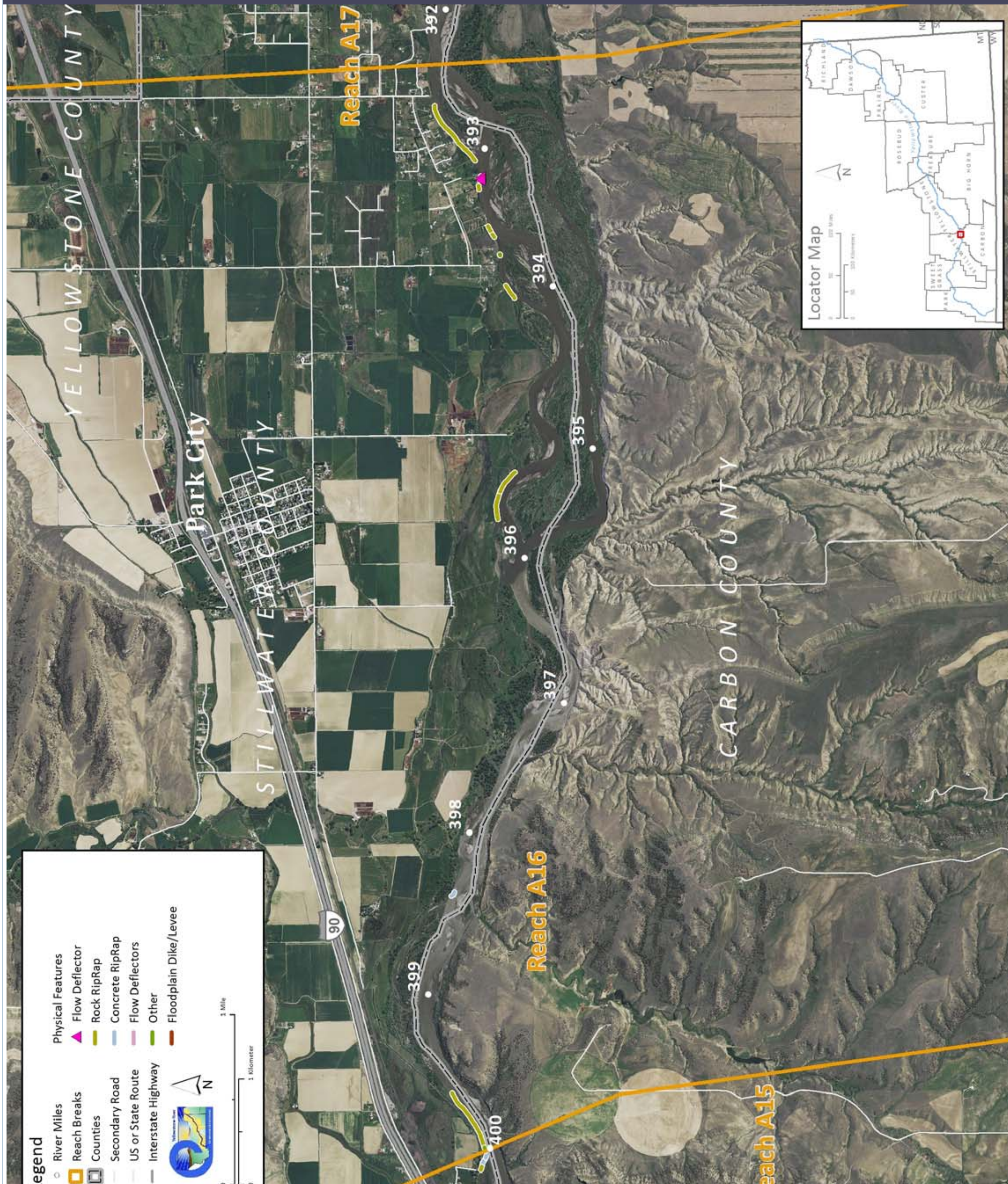
The reach has extensive Russian olive, with almost 30 acres of mapped footprint in the reach.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 16,900 cfs to 15,500 cfs, a drop of about 8 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,310 cfs to 1,780 cfs with human development, a reduction of 23 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A16 include:
•Passive loss of over a mile of side channel
•Russian olive colonization in abandoned side channels
•Emergent wetland development in abandoned side channels

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A16 include:
•Diversion structure management at Italian Ditch Diversion RM 400
•Nutrient management at corrals that are part of an animal handling facility at RM 395.
•Russian olive removal (29 acres)
•Wetland management/restoration due to extent of mapped emergent wetland (214 acres emergent, 270 acres total wetland)

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	28.0	106.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	16,900	32,200	40,100	44,900	54,600	58,600	67,500	2,310	1,760
Regulated	15,500	30,600	38,600	43,500	53,500	57,600	66,900	1,780	1,680
% Change	-8.28%	-4.97%	-3.74%	-3.12%	-2.01%	-1.71%	-0.89%	-22.94%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	5/16/51 - 5/17/1951	B/W	1:28,400	6192500	6000
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	24-Aug-96	B/W		6192500	3540
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2004	Merrick	14-May-04	Color	1:15,840	6192500	4520
2005	NAIP	07/12/2005	color	1-meter pixels	6192500	5960
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2009	NAIP	6/29/2009	Color	1-meter pixels	6192500	13900
2011	USCOE	October 2012	color	1-ft pixel	6192500	2530
2011	NAIP	7/24/2011	Color	1-meter pixels	6192500	13100
2013	NAIP	06/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	4,439	5.5%	6,790	8.4%	2,351
	Flow Deflectors	0	0.0%	90	0.1%	90
	Concrete RipRap	167	0.2%	9	0.0%	-158
	Car Bodies	117	0.1%	117	0.1%	0
	Between Flow Deflectors	0	0.0%	38	0.0%	38
	Feature Type Totals	**4,723**	**5.8%**	**7,043**	**8.7%**	**2,321**
	Reach Totals	**4,723**	**5.8%**	**7,043**	**8.7%**	**2,321**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Car Bodies	0	0	79	0	0	0	0	36
Concrete RipRap	0	157	0	0	0	0	0	0
Rock RipRap	0	977	1,988	0	0	0	0	2,450
Totals	**0**	**1,135**	**2,066**	**0**	**0**	**0**	**0**	**2,486**

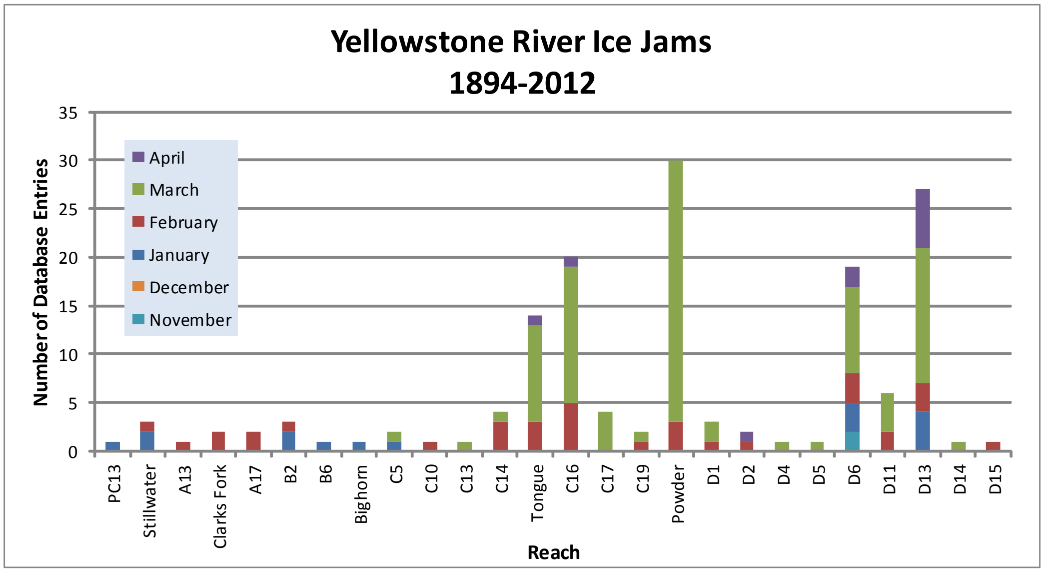
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

Feature Class	Feature Type	Sum of Feature Length (ft) 1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	22,187	22,187	22,187	22,187	22,187	22,187
	Totals	**22,187**	**22,187**	**22,187**	**22,187**	**22,187**	**22,187**
Stream Stabilization							
	Rock RipRap	1,441	1,441	1,976	5,043	5,949	5,949
	Concrete RipRap	0	0	262	262	262	262
	Car Bodies	79	79	112	112	112	112
	Totals	**1,521**	**1,521**	**2,350**	**5,418**	**6,324**	**6,324**
Transportation Encroachment							
	Railroad	4,239	4,239	4,239	4,239	4,239	4,239
	Other	1,669	1,669	1,669	1,669	1,669	1,669
	Totals	**5,908**	**5,908**	**5,908**	**5,908**	**5,908**	**5,908**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	39,915	59,568	2.49	**1950 to 1976:**	6.26%
1976	39,509	65,125	2.65	**1976 to 1995:**	-12.30%
1995	40,855	54,038	2.32	**1995 to 2001:**	0.11%
2001	40,532	53,715	2.33	**1950 to 2001:**	-6.71%
Change 1950 - 2001	**618**	**-5,854**	**-0.17**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	815		1108	
Total Floodplain Area (Ac)	815		1151	
Total Isolated (Ac)	**0**	**0.0%**	**42**	**12.5%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	5	0	0	**5**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
335	671	1,894	61	3%	88	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Irrigated	44	2.2%
	Exurban Residential	15	0.8%
	Canal	46	2.3%
	Totals	**104**	**5.2%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
110.1	0.0	0.0	38.9	0.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	25	25	25	25	0.5%	0.5%	0.5%	0.5%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	46	66	118	108	0.9%	1.2%	2.2%	2.0%
	Totals	**71**	**91**	**142**	**133**	**1.3%**	**1.7%**	**2.6%**	**2.5%**
Agricultural Land									
	Non-Irrigated	2,421	2,331	2,519	2,427	44.9%	43.2%	46.7%	45.0%
	Irrigated	1,588	1,551	1,156	1,106	29.4%	28.7%	21.4%	20.5%
	Totals	**4,009**	**3,883**	**3,674**	**3,533**	**74.3%**	**71.9%**	**68.1%**	**65.4%**
Channel									
	Channel	1,297	1,349	1,252	1,391	24.0%	25.0%	23.2%	25.8%
	Totals	**1,297**	**1,349**	**1,252**	**1,391**	**24.0%**	**25.0%**	**23.2%**	**25.8%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	80	7	0.0%	0.0%	1.5%	0.1%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	2	176	261	0.0%	0.0%	3.3%	4.8%
	Totals	**0**	**2**	**256**	**268**	**0.0%**	**0.0%**	**4.7%**	**5.0%**
Transportation									
	Public Road	11	11	11	11	0.2%	0.2%	0.2%	0.2%
	Interstate	0	52	52	52	0.0%	1.0%	1.0%	1.0%
	Railroad	11	11	11	11	0.2%	0.2%	0.2%	0.2%
	Totals	**21**	**74**	**74**	**74**	**0.4%**	**1.4%**	**1.4%**	**1.4%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	11	11	0.0%	0.0%	0.3%	0.3%	0.0%	0.3%	0.0%	0.3%
	Flood	1,588	1,551	1,145	1,095	39.6%	40.0%	31.2%	31.0%	0.3%	-8.8%	-0.2%	-8.6%
	Totals	**1,588**	**1,551**	**1,156**	**1,106**	**39.6%**	**40.0%**	**31.5%**	**31.3%**	**0.3%**	**-8.5%**	**-0.2%**	**-8.3%**

Non-Irrigated												
Multi-Use	2,349	1,976	1,894	1,798	58.6%	50.9%	51.5%	50.9%	-7.7%	0.7%	-0.7%	-7.7%
Hay/Pasture	72	356	625	629	1.8%	9.2%	17.0%	17.8%	7.4%	7.8%	0.8%	16.0%
Totals	**2,421**	**2,331**	**2,519**	**2,427**	**60.4%**	**60.0%**	**68.5%**	**68.7%**	**-0.3%**	**8.5%**	**0.2%**	**8.3%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.7	0.2	0.7	1.4	0.3	0.9	1.8	1.4	1.8
Max	128.0	83.6	72.3	90.3	244.8	245.1	198.1	92.8	38.6
Average	15.2	8.7	10.7	23.2	17.0	29.2	22.4	15.0	26.7
Sum	273.5	182.0	171.6	440.6	610.9	672.2	291.8	149.8	133.4

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	225.6
Channel to Riparian (acres)	220.7
Riparian Encroachment (acres)	**-5.0**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	222.2
1950s Floodplain Mapped as 2011 Channel (Ac)	121.8
Total Recruitment (1950s to 2011)(Ac)	**344.0**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	10.7	214.0	43.3	0.0	**268.0**
Acres/Valley Mile	1.6	32.0	6.5	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	28.74	1.83%	19.92	0.17	10.47	9.07

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	223.2	102.4	8.2%
Rip Rap Bottom	34.8	16.6	1.3%
Bluff Pool	63.2	47.7	3.8%
Terrace Pool	18.5	9.8	0.8%
Secondary Channel	62.0	74.5	6.0%
Secondary Channel (Seasonal)	179.2	100.8	8.0%
Channel Crossover	200.6	121.5	9.7%
Point Bar		60.4	4.8%
Side Bar		51.2	4.1%
Mid-channel Bar		64.5	5.2%
Island	470.6	473.6	37.8%
Dry Channel		129.2	10.3%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern Potential Species of Concern

Reach	Region	Species
✓	✓	American Robin
✓	✓	American Crow
✓	✓	American Goldfinch
		American Kestrel
✓	✓	American Redstart
		Bald Eagle
✓	✓	Baltimore Oriole
	✓	Barn Swallow
		Belted Kingfisher
		Black-billed Cuckoo
✓	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
	✓	Black-and-white Warbler
✓	✓	Black-headed Grosbeak
	✓	Blue Jay
	✓	Bobolink
	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
		Brown Creeper
	✓	Brown Thrasher
✓	✓	Bullock's Oriole
		Canada Goose
✓	✓	Cedar Waxwing
	✓	Chimney Swift
	✓	Chipping Sparrow
✓	✓	Clay-collared Sparrow
	✓	Cliff Swallow
	✓	Common Grackle
		Common Merganser
		Common Nighthawk
		Common Raven
✓	✓	Common Yellowthroat
		Cooper's Hawk
	✓	Dickcissel
✓	✓	Downy Woodpecker
		Eastern Bluebird
✓	✓	Eastern Kingbird
		Eurasian Collared-dove
✓	✓	European Starling
✓	✓	Field Sparrow
		Franklin's Gull
		Grasshopper Sparrow
✓	✓	Gray Catbird
		Great Blue Heron
		Great Horned Owl
✓	✓	Hairy Woodpecker
		House Finch
✓	✓	House Wren
		Killdeer
		Lark Bunting
	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
		Mallard
	✓	Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
		Orchard Oriole
		Osprey
	✓	Ovenbird
		Plumbeous Vireo
		Red-headed Woodpecker
	✓	Red-naped Sapsucker
		Red Crossbill
		Ring-necked Pheasant
		Red-tailed hawk
		Rock Dove
✓	✓	Red-winged Blackbird
✓	✓	Red-eyed Vireo
		Red-breasted Grosbeak
		Say's Phoebe
	✓	Savannah Sparrow
✓	✓	Song Sparrow
		Spotted Sandpiper
✓	✓	Spotted Towhee
		Sharp-shinned Hawk
	✓	Swainson's Thrush
		Sandhill Crane
✓	✓	Tree Swallow
		Turkey Vulture
		Upland Sandpiper
	✓	Vesper Sparrow
	✓	Violet-green Swallow
✓	✓	Warbling Vireo
✓	✓	Western Kingbird
	✓	Western Meadowlark
✓	✓	Western Wood-pewee
✓	✓	White-breasted Nuthatch
	✓	White-throated Swift
		Wild Turkey
		Wood Duck
		Yellow-bellied Sapsucker
		Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
	✓	Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Yellowstone	**Upstream River Mile**	392.4
Classification	UA: Unconfined anabranching	**Downstream River Mile**	386
General Location	To Laurel	**Length**	6.40 mi (10.30 km)
General Comments	To Laurel; WAI Reach A		

Narrative Summary

Reach A17 is 7.6 miles long and is located just above Laurel. The reach is classified as Unconfined Anabranching (UA), which is characteristically one of the most dynamic reach types on the river. The river is flowing in the alluvial valley with minimal influences of the valley wall and through numerous forested islands. There are sites in Reach A17 where the river has migrated almost 1,000 feet since 1950.

Approximately 13 percent of the bankline in Reach A17 is armored by rock riprap, concrete riprap and flow deflectors. Between 2001 and 2011 the total length of rock riprap increased by about a half of a mile. At RM 387, a ~750 foot long stretch of flow deflectors on the left bank have been flanked, and by fall 2011 the river had migrated about 120 feet behind the flanked armor. The deflectors are still visible in the channel. In some places such as at RM 389.8, bank armor on both sides of the river narrows the corridor to about one channel width, or 1,000 feet.

Over a mile of side channels in Reach A17 were blocked prior to 1950. Two major channels were blocked on the north side of the river, one at the Buffalo Mirage Fishing Access Site at RM 391.5, and the other at Rm 389.5. These channels, as well as other secondary channels that were passively loss, host fairly dense concentrations of Russian olive. Similar to most reaches in Region A, the loss of side channels has been accompanied by an increase in the total river footprint, indicating that flow concentration into the main river channel has caused it to enlarge. Between 1950 and 2001, the size of the channel increased from 560 acres to 645 acres.

Land use in Reach A17 is primarily agricultural, although there are almost 600 acres of urban/exurban development in the reach as the river approaches the City of Laurel. Since 1950, there has been a reduction in flood irrigated acres of about 550 acres, and an increase in pivot irrigation from 0 acres in 1950 to 284 acres in 2011. A total of 383 acres of developed ground are in the mapped Channel Migration Zone; and about 11 percent of the CMZ has been isolated by physical features protecting those land uses.

At RM 388.5, a headgate diverts water into an old side channel that has been converted to a canal on the north side of the river. About ½ mile downstream, the canal is riprapped where it was recently threatened by rapid northward river migration. At this location, the river has migrated over 800 feet northward since 1950. The main channel of the river now flows along the riprapped canal embankment for about 750 feet.

There are corrals that are part of an animal handling facility within 600 feet of the north riverbank at RM 392.

Side channel loss and channel migration in Reach A17 has resulted in relatively high rates of riparian recruitment. Since 1950, there has been 330 acres of land that experience recruitment of new riparian vegetation. Most of that recruitment was in abandoned channels (200 acres) and about 27 acres of recruitment was direct result of channel migration.

Two ice jams have been recorded in Reach A17, in 1996 and 1997. Both occurred during the month of February, and were reported to have occurred at the Laurel Bridge.

There are over 200 acres of mapped wetland in the reach, with most of that emergent marshes and wet meadows. Many of these wetland areas occupy river swales on the floodplain north of the river, or abandoned channels in the active corridor.

Almost 22 acres of Russian olive has been mapped in the floodplain.

Reach A17 was sampled as part of the avian study. The average species richness in Reach A17 was 7.7, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for all sites evaluated is 8. An average of 0.9 Cowbirds (a bird that parasitizes other bird's nests) were observed in cottonwood habitats during the field sampling visits. Reach A17 has lost about two thirds of its riparian forest considered at low risk of cowbird parasitism since 1950. At that time, there were about 28 acres of forest per valley mile considered to be isolated enough from agricultural infrastructure and urban/exurban development to be considered at low risk. By 2011, about 10 acres per valley mile considered low risk remained.

A total of three Potential Species of Concern (PSOCs) were observed in Reach A17 during the avian study, including the Black and White Warbler, Chimney Swift, and Ovenbird. One Species of Concern (SOC), the Bobolink, was also observed in Reach A17.

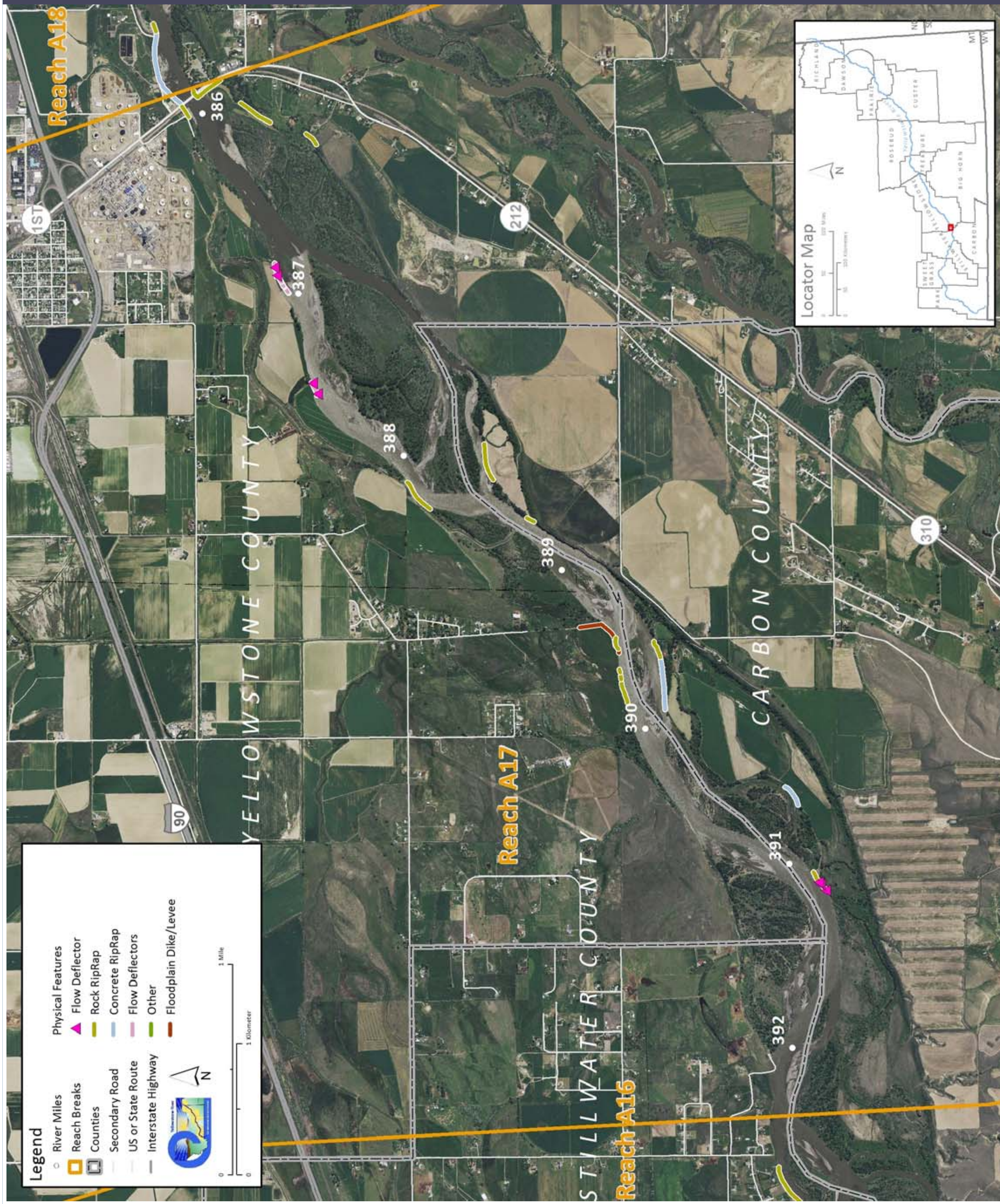
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 16,900 cfs to 15,500 cfs, a drop of about 8 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,320 cfs to 1,780 cfs with human development, a reduction of 23 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A17 include:
•Flanking of flow deflectors and accelerated erosion behind flanked structures

•Physical blockage of over a mile of side channel
•Russian olive colonization in abandoned side channels
•Emergent wetland development in abandoned side channels
•Ice jamming potentially associated with the Laurel Bridge

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A17 include:
•Bank armor removal (flanked flow deflectors), RM 387
•Side channel restoration at RM 391.5 and RM 389.5
•Nutrient management associated with corrals that are part of an animal handling facility at RM 392.
•Russian olive removal (22 acres)
•Wetland management/restoration due to extent of mapped wetland (200 acres)
•Irrigation diversion structure management at headgate on side channel at RM 388.5

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	21.6	114.2

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	16,900	32,200	40,100	44,900	54,600	58,600	67,500	2,320	1,760
Regulated	15,500	30,600	38,600	43,500	53,500	57,600	66,900	1,780	1,680
% Change	-8.28%	-4.97%	-3.74%	-3.12%	-2.01%	-1.71%	-0.89%	-23.28%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	5/14/51 - 6/9/51	B/W	1:28,400	6192500	6000
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	23-Aug-96	B/W		6192500	3730
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2004	Merrick	14-May-04	Color	1:15,840	6192500	4520
2005	NAIP	07/12/2005	color	1-meter pixels	6192500	5960
2005	NAIP	07/08/2005	color	1-meter pixels	6192500	6410
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	USCOE	October 2012	color	1-ft pixel	6192500	2530
2011	NAIP	7/24/2011	Color	1-meter pixels	6192500	13100
2013	NAIP	06/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	3,601	5.3%	6,185	9.1%	2,584
	Flow Deflectors	236	0.3%	230	0.3%	-6
	Concrete RipRap	2,205	3.2%	2,205	3.2%	0
	Between Flow Deflectors	612	0.9%	441	0.6%	-171
	Feature Type Totals	**6,653**	**9.7%**	**9,061**	**13.3%**	**2,408**
Floodplain Control						
	Floodplain Dike/Levee	1,434	2.1%	1,434	2.1%	0
	Feature Type Totals	**1,434**	**2.1%**	**1,434**	**2.1%**	**0**
	Reach Totals	**8,087**	**11.8%**	**10,495**	**15.4%**	**2,408**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	1,227	0	659	0	0	0	0	0
Flow Deflectors/Between FDs	846	0	0	0	0	0	0	0
Rock RipRap	1,132	0	1,250	1,207	0	0	0	0
Totals	**3,205**	**0**	**1,909**	**1,207**	**0**	**0**	**0**	**0**

Bankline/Floodplain Inventory: Time Series

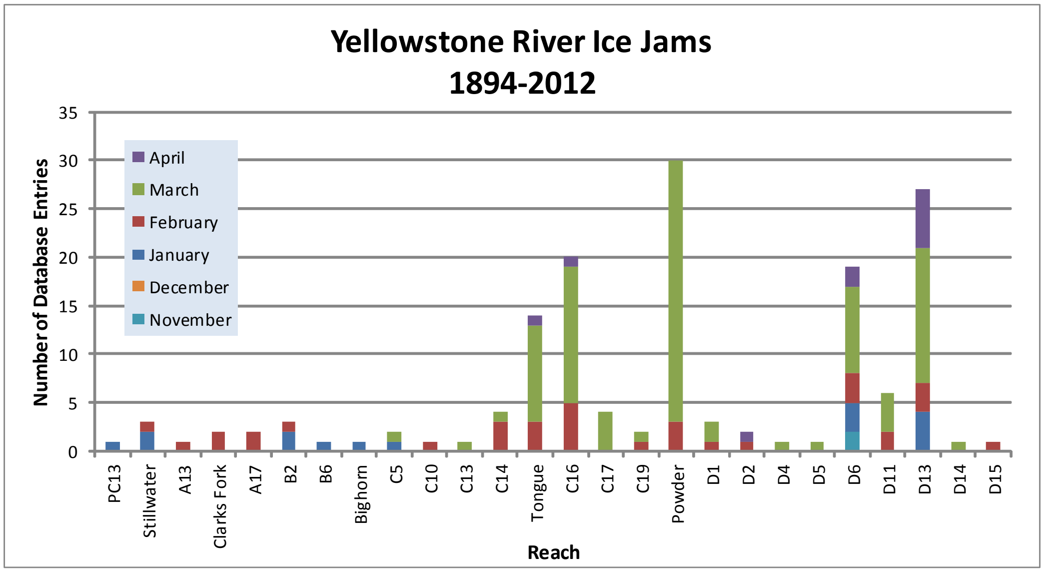
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	32,154	32,838	32,838	33,205	33,965	33,965
	Totals	**32,154**	**32,838**	**32,838**	**33,205**	**33,965**	**33,965**
Other							
	Floodplain Dike/Levee	0	2,677	2,677	2,677	2,677	2,677
	Totals	**0**	**2,677**	**2,677**	**2,677**	**2,677**	**2,677**
Other Off Channel							
	Other	2,200	2,200	2,200	2,200	2,200	2,200
	Floodplain Dike/Levee	0	0	0	412	412	412
	Floodplain Dike/Levee	361	576	576	576	576	576
	Totals	**2,562**	**2,776**	**2,776**	**3,189**	**3,189**	**3,189**
Stream Stabilization							
	Rock RipRap	272	3,692	3,886	4,200	4,200	4,200

	Flow Deflector	0	0	0	812	812	812
	Concrete RipRap	366	988	988	3,055	3,645	3,645
	Totals	**638**	**4,681**	**4,875**	**8,066**	**8,656**	**8,656**
Transportation Encroachment							
	Floodplain Dike/Levee	5,461	5,461	5,461	5,461	5,461	5,461
	Bridge Approach	3,994	3,994	3,994	3,994	3,994	3,994
	Totals	**9,455**	**9,455**	**9,455**	**9,455**	**9,455**	**9,455**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
2/6/1996	NA	386	Flooding
2/21/1997	Freeze-up	386	?

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	34,729	37,999	2.09
1976	34,084	38,322	2.12
1995	34,298	29,134	1.85
2001	34,137	31,373	1.92
Change 1950 - 2001	**-592**	**-6,626**	**-0.18**

	% Change in Braiding
1950 to 1976:	1.44%
1976 to 1995:	-12.94%
1995 to 2001:	3.76%
1950 to 2001:	-8.36%

Length of Side Channels Blocked

Pre-1950s (ft)	7,639
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	10	0.8%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	80	5.9%		
Total Not Isolated (Ac)	1253		1092	
Total Floodplain Area (Ac)	1343		1139	
Total Isolated (Ac)	**90**	**6.7%**	**46**	**9.4%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	49	0	0	**49**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
457	914	2,173	192	9%	78	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Public Road	16	0.7%
	Non-Irrigated	45	2.0%
	Irrigated	114	5.0%
	Canal	23	1.0%
Flow Deflectors			
	Irrigated	25	1.1%
Dike/Levee			
	Irrigated	23	1.0%
	Totals	**246**	**10.9%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
358.9	0.0	0.0	18.7	5.7

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	15	15	15	15	0.3%	0.3%	0.3%	0.3%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	54	75	97	103	0.9%	1.3%	1.7%	1.8%
	Totals	**69**	**90**	**112**	**118**	**1.2%**	**1.6%**	**1.9%**	**2.1%**
Agricultural Land									
	Non-Irrigated	2,603	2,243	2,491	2,442	45.2%	39.0%	43.3%	42.4%
	Irrigated	1,927	2,113	1,736	1,668	33.5%	36.7%	30.2%	29.0%
	Totals	**4,530**	**4,356**	**4,227**	**4,110**	**78.7%**	**75.6%**	**73.4%**	**71.4%**
Channel									
	Channel	954	984	934	983	16.6%	17.1%	16.2%	17.1%
	Totals	**954**	**984**	**934**	**983**	**16.6%**	**17.1%**	**16.2%**	**17.1%**
ExUrban									
	ExUrban Other	2	2	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	6	25	62	76	0.1%	0.4%	1.1%	1.3%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	51	52	168	216	0.9%	0.9%	2.9%	3.8%
	Totals	**59**	**80**	**230**	**292**	**1.0%**	**1.4%**	**4.0%**	**5.1%**
Transportation									
	Public Road	41	41	41	41	0.7%	0.7%	0.7%	0.7%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	10	10	10	10	0.2%	0.2%	0.2%	0.2%
	Totals	**50**	**50**	**50**	**50**	**0.9%**	**0.9%**	**0.9%**	**0.9%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	21	21	21	0.0%	0.4%	0.4%	0.4%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	22	0	0	0	0.4%	0.0%	0.0%	0.0%
	Urban Industrial	74	177	182	182	1.3%	3.1%	3.2%	3.2%
	Totals	**95**	**199**	**204**	**204**	**1.7%**	**3.5%**	**3.5%**	**3.5%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	203	284	284	0.0%	4.7%	6.7%	6.9%	4.7%	2.1%	0.2%	6.9%
	Flood	1,927	1,910	1,452	1,384	42.5%	43.8%	34.4%	33.7%	1.3%	-9.5%	-0.7%	-8.9%
	Totals	**1,927**	**2,113**	**1,736**	**1,668**	**42.5%**	**48.5%**	**41.1%**	**40.6%**	**6.0%**	**-7.4%**	**-0.5%**	**-2.0%**

Non-Irrigated												
Multi-Use	1,484	1,093	1,201	1,182	32.8%	25.1%	28.4%	28.8%	-7.7%	3.3%	0.4%	-4.0%
Hay/Pasture	1,119	1,150	1,290	1,260	24.7%	26.4%	30.5%	30.7%	1.7%	4.1%	0.1%	6.0%
Totals	**2,603**	**2,243**	**2,491**	**2,442**	**57.5%**	**51.5%**	**58.9%**	**59.4%**	**-6.0%**	**7.4%**	**0.5%**	**2.0%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.2	0.5	0.0	0.3	0.0	1.0	2.4	1.3	0.4
Max	22.7	88.6	21.9	213.6	142.1	156.2	89.4	52.3	129.8
Average	5.5	16.6	5.6	36.2	22.2	32.2	19.9	21.3	22.1
Sum	83.1	182.6	78.5	723.3	777.5	677.1	258.8	191.6	331.4

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	255.8
Channel to Riparian (acres)	236.0
Riparian Encroachment (acres)	**-19.8**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	227.5
1950s Floodplain Mapped as 2011 Channel (Ac)	100.2
Total Recruitment (1950s to 2011)(Ac)	**327.7**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	9.4	203.4	13.4	0.0	**226.2**
Acres/Valley Mile	1.6	35.6	2.3	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	21.84	6.68%	182.62	1.10	3.47	1.43

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	295.5	157.8	16.9%
Rip Rap Bottom	17.4	10.7	1.1%
Terrace Pool	16.4		
Secondary Channel	19.3	54.9	5.9%
Secondary Channel (Seasonal)	143.8	82.1	8.8%
Channel Crossover	147.2	72.5	7.8%
Point Bar		23.6	2.5%
Side Bar		54.9	5.9%
Mid-channel Bar		86.8	9.3%
Island	294.8	292.8	31.3%
Dry Channel		98.2	10.5%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern Potential Species of Concern

Reach	Region	Species
✓	✓	American Robin
✓	✓	American Crow
✓	✓	American Goldfinch
☐	☐	American Kestrel
✓	✓	American Redstart
☐	☐	Bald Eagle
☐	☐	Baltimore Oriole
☐	✓	Barn Swallow
☐	☐	Belted Kingfisher
☐	☐	Black-billed Cuckoo
✓	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
✓	✓	Black-and-white Warbler
✓	✓	Black-headed Grosbeak
☐	✓	Blue Jay
✓	✓	Bobolink
☐	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
☐	☐	Brown Creeper
✓	✓	Brown Thrasher
✓	✓	Bullock's Oriole
☐	☐	Canada Goose
✓	✓	Cedar Waxwing
✓	✓	Chimney Swift
☐	✓	Chipping Sparrow
☐	✓	Clay-collared Sparrow
☐	✓	Cliff Swallow
✓	✓	Common Grackle
☐	☐	Common Merganser
☐	☐	Common Nighthawk
☐	☐	Common Raven
✓	✓	Common Yellowthroat
☐	☐	Cooper's Hawk
☐	✓	Dickcissel
✓	✓	Downy Woodpecker
☐	☐	Eastern Bluebird
☐	✓	Eastern Kingbird
☐	☐	Eurasian Collared-dove
✓	✓	European Starling
☐	✓	Field Sparrow
☐	☐	Franklin's Gull
☐	☐	Grasshopper Sparrow
✓	✓	Gray Catbird
☐	☐	Great Blue Heron
☐	☐	Great Horned Owl
✓	✓	Hairy Woodpecker
☐	☐	House Finch
✓	✓	House Wren
☐	☐	Killdeer
☐	☐	Lark Bunting
☐	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
☐	☐	Mallard
☐	✓	Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
☐	☐	Orchard Oriole
☐	☐	Osprey
✓	✓	Ovenbird
☐	☐	Plumbeous Vireo
☐	☐	Red-headed Woodpecker
☐	✓	Red-naped Sapsucker
☐	☐	Red Crossbill
☐	☐	Ring-necked Pheasant
☐	☐	Red-tailed hawk
☐	☐	Rock Dove
✓	✓	Red-winged Blackbird
✓	✓	Red-eyed Vireo
☐	☐	Red-breasted Grosbeak
☐	☐	Say's Phoebe
☐	✓	Savannah Sparrow
✓	✓	Song Sparrow
☐	☐	Spotted Sandpiper
✓	✓	Spotted Towhee
☐	☐	Sharp-shinned Hawk
☐	✓	Swainson's Thrush
☐	☐	Sandhill Crane
✓	✓	Tree Swallow
☐	☐	Turkey Vulture
☐	☐	Upland Sandpiper
☐	✓	Vesper Sparrow
☐	✓	Violet-green Swallow
✓	✓	Warbling Vireo
✓	✓	Western Kingbird
✓	✓	Western Meadowlark
✓	✓	Western Wood-pewee
☐	✓	White-breasted Nuthatch
☐	✓	White-throated Swift
☐	☐	Wild Turkey
☐	☐	Wood Duck
☐	☐	Yellow-bellied Sapsucker
☐	☐	Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
☐	✓	Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Yellowstone	**Upstream River Mile**	386
Classification	UA: Unconfined anabranching	**Downstream River Mile**	383.5
General Location	To Clarks Fork	**Length**	2.50 mi (4.02 km)
General Comments	To Clark Fork; land use change to row crops; WAI Reach A		

Narrative Summary

Reach A18 is 2.5 miles long and extends from Laurel to the mouth of the Clarks Fork River. The reach is classified as Unconfined Anabranching (UA), which is characteristically one of the most dynamic reach types on the river. The reach has one large island and even though it is fairly intensively armored through Laurel, there has been over 1,100 feet of southward channel migration since 1950 at one location about ½ mile downstream of the bridge.

Reach A18 is perhaps best known by the series of pipeline crossings below the Laurel Bridge. In 2011, floodwaters on the Yellowstone River peaked on July 2 at 70,600 cfs, which is an estimated 25-50 year flood event. On July 1, the day before the peak, a 12-inch diameter crude oil pipeline called the ExxonMobil Silvertip Pipeline, ruptured just downstream of the bridge in Reach A18. The pipeline was originally installed in a trench across the river that was 5-7 feet deep. The rupture spilled an estimated 50,000 gallons of oil into the Yellowstone River; the incident received national attention and millions of dollars were spent on cleanup. The Silvertip Pipeline and several others at this location have been replaced by HDD (Horizontal Directionally Drilled) lines.

The industrial land uses at Laurel uses coupled with the dynamic nature of the Yellowstone River in Reach A18 has resulted in the armoring of almost 40 percent of the river in this reach. That armor consists of rock riprap, concrete riprap, and flow deflectors. Almost all of the armor is located on the north bank where it protects the City of Laurel sewage treatment facility, as well as a canal that leaves the river at RM 385.7. There is one small section of concrete armor on the north bank, and it appears that the upper 300 feet of this armor has been flanked and now is visible in the middle of the river. Recent concerns over the main intake structure for the city's water supply sheds some light on the dynamics of the river, and potentially the influence of high density bank armor on channel stability. The 2011 flood evidently caused the river to downcut at the intake, perching the structure, such that there are current efforts in motion to relocate the intake several miles upstream. This downcutting may be related to the high density of armor between Laurel and Billings that effectively focuses flow into the main channel and can drive channel incision (downcutting). Reach conditions just downstream in Reach B1 support this hypothesis.

There are over three miles of mapped dikes in Reach A18. Dikes, levees, and transportation encroachment features have isolated about one half of the historic 100-year floodplain in the reach. Almost 17 percent of the 5-year floodplain has become isolated from the river. Most of the isolated 100-year floodplain area is south of the river, between the Yellowstone and Clarks Fork Rivers.

Land use in Reach A18 is primarily agricultural, although there are almost 380 acres of urban/exurban development in the reach as the river passes south of the City of Laurel. All of the irrigated land in Reach A18 is in flood irrigation. A total of 110 acres of developed ground are in the mapped Channel Migration Zone; and the over 90 percent of that is in urban/exurban land use. A total of 31 percent of the CMZ has become isolated by physical features.

Riparian mapping indicates that since 1950, about 67 acres in the reach were cleared to support irrigation and other land uses. There are about 18 acres of mapped Russian olive in the floodplain.

Since 1950, about 150 acres of land in Reach A18 was colonized by new riparian vegetation. There are over 140 acres of mapped emergent wetland in the reach, which consists primarily of emergent marshes and wet meadows.

Almost 18 acres of Russian olive has been mapped in the floodplain.

Reach A18 was sampled as part of the avian study. The average species richness in Reach A17 was 7.1, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for all sites evaluated is 8. On average, of 0.9 Cowbirds were observed in cottonwood habitats during the field sampling visits. Reach A18 has lost all of its riparian forest considered at low risk of cowbird parasitism since 1950. At that time, there were 3.4 acres of forest per valley mile considered to be isolated enough from agricultural infrastructure and urban/exurban development to be considered at low risk. By 2011, that had been reduced to zero.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 16,900 cfs to 15,500 cfs, a drop of about 8 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,780 cfs to 1,950 cfs with human development, a reduction of 30 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A18 include:
•Flanking of concrete armor
•Pipeline rupture in highly armored reach
•Water intake perching in highly armored reach
•Russian olive colonization
•Emergent wetland development in abandoned side channels

•Floodplain isolation at confluence between Clarks Fork and Yellowstone River from transportation-related infrastructure
•Extensive CMZ encroachment in urbanized reach

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A18 include:
•Irrigation diversion structure management at headgate on at a canal at RM 385.7
•Flanked concrete armor removal RM 384
•Russian olive removal (18 acres)
•Floodplain restoration between lower Clarks Fork River and Yellowstone River
•Pipeline Management for several crossings at Laurel.

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	19.1	120.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	16,900	32,200	40,100	44,900	54,600	58,600	67,500	2,780	1,760
Regulated	15,500	30,600	38,600	43,500	53,500	57,600	66,900	1,950	1,680
% Change	-8.28%	-4.97%	-3.74%	-3.12%	-2.01%	-1.71%	-0.89%	-29.86%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	14-May-51	B/W	1:28,400	6192500	5520
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	23-Aug-96	B/W		6192500	3730
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2004	Merrick	14-May-04	Color	1:15,840	6192500	4520
2005	NAIP	07/12/2005	color	1-meter pixels	6192500	5960
2005	NAIP	07/08/2005	color	1-meter pixels	6192500	6410
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	USCOE	October 2012	color	1-ft pixel	6192500	2530
2011	NAIP	7/24/2011	Color	1-meter pixels	6192500	13100
2013	NAIP	06/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	3,665	14.7%	3,885	15.6%	220
	Flow Deflectors	570	2.3%	628	2.5%	58
	Concrete RipRap	4,519	18.2%	3,783	15.2%	-736
	Car Bodies	190	0.8%	190	0.8%	0
	Between Flow Deflectors	897	3.6%	897	3.6%	0
	Feature Type Totals	**9,841**	**39.6%**	**9,382**	**37.7%**	**-459**
	Reach Totals	**9,841**	**39.6%**	**9,382**	**37.7%**	**-459**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Car Bodies	0	190	0	0	0	0	0	0
Concrete RipRap	1,968	754	538	262	0	0	0	1,640
Flow Deflectors/Between FDs	0	0	1,466	0	0	0	0	0
Rock RipRap	0	0	1,653	2,011	0	0	0	0
Totals	**1,968**	**945**	**3,657**	**2,273**	**0**	**0**	**0**	**1,640**

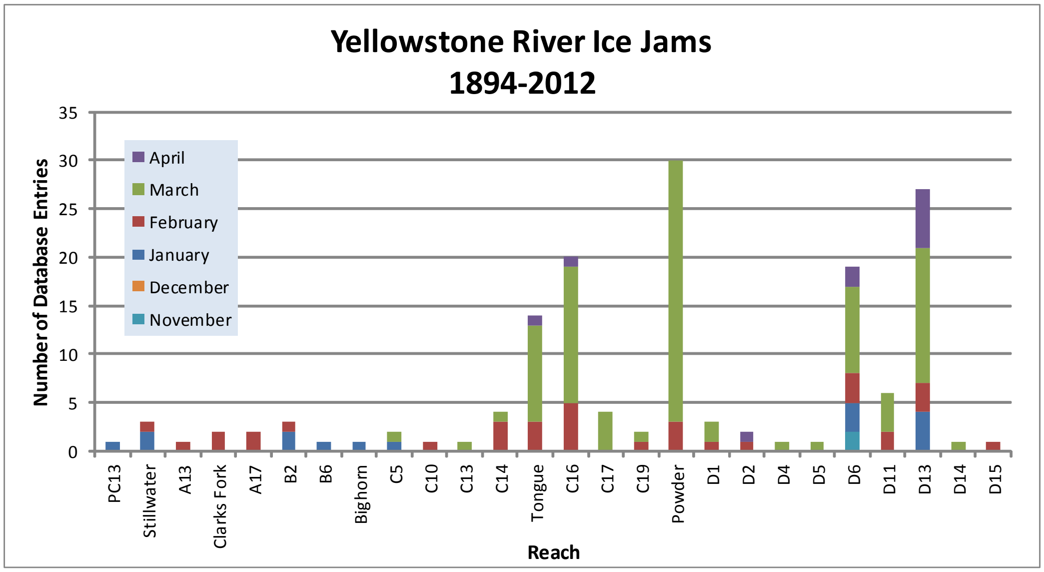
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	18,079	19,411	20,171	20,171	20,171	20,171
	Totals	**18,079**	**19,411**	**20,171**	**20,171**	**20,171**	**20,171**
Stream Stabilization							
	Rock RipRap	121	2,374	2,374	3,576	3,576	3,576
	Flow Deflector	0	0	0	1,467	1,467	1,467
	Concrete RipRap	2,825	2,825	2,825	4,648	4,648	4,648
	Car Bodies	0	0	569	569	569	569
	Totals	**2,946**	**5,199**	**5,769**	**10,260**	**10,260**	**10,260**
Transportation Encroachment							
	Other	912	912	912	912	912	912
	County Road	11,313	13,192	13,192	13,192	13,192	13,192
	Bridge Approach	1,153	1,153	1,153	1,153	1,153	1,153
	Totals	**13,377**	**15,257**	**15,257**	**15,257**	**15,257**	**15,257**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	13,798	13,021	1.94	1950 to 1976:	23.49%
1976	12,653	17,718	2.40	1976 to 1995:	-13.22%
1995	12,533	13,573	2.08	1995 to 2001:	5.22%
2001	12,433	14,814	2.19	1950 to 2001:	12.76%
Change 1950 - 2001	**-1,366**	**1,794**	**0.25**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	34	6.1%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	269	47.9%		
Total Not Isolated (Ac)	258		354	
Total Floodplain Area (Ac)	562		369	
Total Isolated (Ac)	**304**	**54.0%**	**15**	**17.0%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	1	0	0	**1**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
379	759	884	275	31%	0	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	13	1.5%
RipRap			
	Urban Industrial	37	4.2%
	Public Road	88	9.9%
	Canal	97	11.0%
Flow Deflectors			
	Canal	39	4.4%
	Totals	**275**	**31.1%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
0.0	0.0	0.0	100.9	8.6

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	22	22	22	22	0.8%	0.8%	0.8%	0.8%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	25	40	28	25	0.9%	1.4%	1.0%	0.9%
	Totals	**47**	**62**	**49**	**46**	**1.6%**	**2.2%**	**1.7%**	**1.6%**
Agricultural Land									
	Non-Irrigated	1,456	999	986	874	50.7%	34.8%	34.4%	30.5%
	Irrigated	946	904	861	894	33.0%	31.5%	30.0%	31.1%
	Totals	**2,402**	**1,903**	**1,848**	**1,768**	**83.7%**	**66.3%**	**64.4%**	**61.6%**
Channel									
	Channel	368	672	646	657	12.8%	23.4%	22.5%	22.9%
	Totals	**368**	**672**	**646**	**657**	**12.8%**	**23.4%**	**22.5%**	**22.9%**
ExUrban									
	ExUrban Other	0	6	6	0	0.0%	0.2%	0.2%	0.0%
	ExUrban Undeveloped	0	0	0	61	0.0%	0.0%	0.0%	2.1%
	ExUrban Industrial	0	27	35	35	0.0%	0.9%	1.2%	1.2%
	ExUrban Commercial	6	11	21	21	0.2%	0.4%	0.7%	0.7%
	ExUrban Residential	21	154	199	216	0.7%	5.4%	6.9%	7.5%
	Totals	**27**	**198**	**260**	**332**	**0.9%**	**6.9%**	**9.1%**	**11.6%**
Transportation									
	Public Road	23	23	23	23	0.8%	0.8%	0.8%	0.8%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**23**	**23**	**23**	**23**	**0.8%**	**0.8%**	**0.8%**	**0.8%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	1	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	2	11	43	43	0.1%	0.4%	1.5%	1.5%
	Totals	**2**	**11**	**43**	**43**	**0.1%**	**0.4%**	**1.5%**	**1.5%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	946	904	861	894	39.4%	47.5%	46.6%	50.5%	8.1%	-0.9%	3.9%	11.2%
	Totals	**946**	**904**	**861**	**894**	**39.4%**	**47.5%**	**46.6%**	**50.5%**	**8.1%**	**-0.9%**	**3.9%**	**11.2%**

Non-Irrigated												
Multi-Use	1,143	749	875	749	47.6%	39.3%	47.4%	42.3%	-8.2%	8.0%	-5.0%	-5.2%
Hay/Pasture	313	250	111	126	13.0%	13.1%	6.0%	7.1%	0.1%	-7.1%	1.1%	-5.9%
Totals	**1,456**	**999**	**986**	**874**	**60.6%**	**52.5%**	**53.4%**	**49.5%**	**-8.1%**	**0.9%**	**-3.9%**	**-11.2%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	1.3	0.2	1.1	0.0	0.0	1.2	0.3	11.2	2.2
Max	48.1	15.6	36.1	129.9	132.9	148.2	67.2	88.5	61.0
Average	16.7	7.4	14.0	22.2	16.3	20.0	16.5	26.7	23.0
Sum	234.4	103.2	125.9	355.0	341.4	319.6	115.3	160.1	206.9

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	191.3
Channel to Riparian (acres)	134.1
Riparian Encroachment (acres)	**-57.2**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	66.2
1950s Floodplain Mapped as 2011 Channel (Ac)	83.4
Total Recruitment (1950s to 2011)(Ac)	**149.5**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	15.8	139.7	33.2	0.0	**188.7**
Acres/Valley Mile	7.7	68.2	16.2	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	17.94	2.68%	31.36	1.05	1.75	1.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	58.2	46.6	10.1%
Rip Rap Bottom	47.0	4.0	0.9%
Secondary Channel	84.1	55.9	12.1%
Secondary Channel (Seasonal)	67.3	22.0	4.7%
Channel Crossover	24.3	28.1	6.1%
Point Bar		7.7	1.7%
Side Bar		16.7	3.6%
Mid-channel Bar		36.7	7.9%
Island	182.7	182.7	39.4%
Dry Channel		63.3	13.7%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern   Potential Species of Concern

Reach	Region	Species
✓	✓	American Robin
	✓	American Crow
✓	✓	American Goldfinch
		American Kestrel
✓	✓	American Redstart
		Bald Eagle
		Baltimore Oriole
	✓	Barn Swallow
		Belted Kingfisher
		Black-billed Cuckoo
✓	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
	✓	Black-and-white Warbler
✓	✓	Black-headed Grosbeak
	✓	Blue Jay
	✓	Bobolink
	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
		Brown Creeper
	✓	Brown Thrasher
✓	✓	Bullock's Oriole
		Canada Goose
✓	✓	Cedar Waxwing
	✓	Chimney Swift
	✓	Chipping Sparrow
	✓	Clay-collared Sparrow
	✓	Cliff Swallow
	✓	Common Grackle
		Common Merganser
		Common Nighthawk
		Common Raven
✓	✓	Common Yellowthroat
		Cooper's Hawk
	✓	Dickcissel
✓	✓	Downy Woodpecker
		Eastern Bluebird
✓	✓	Eastern Kingbird
		Eurasian Collared-dove
✓	✓	European Starling
	✓	Field Sparrow
		Franklin's Gull
		Grasshopper Sparrow
✓	✓	Gray Catbird
		Great Blue Heron
		Great Horned Owl
✓	✓	Hairy Woodpecker
		House Finch
✓	✓	House Wren
		Killdeer
		Lark Bunting
	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
		Mallard
	✓	Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
		Orchard Oriole
		Osprey
	✓	Ovenbird
		Plumbeous Vireo
		Red-headed Woodpecker
	✓	Red-naped Sapsucker
		Red Crossbill
		Ring-necked Pheasant
		Red-tailed hawk
		Rock Dove
✓	✓	Red-winged Blackbird
	✓	Red-eyed Vireo
		Red-breasted Grosbeak
		Say's Phoebe
	✓	Savannah Sparrow
✓	✓	Song Sparrow
		Spotted Sandpiper
	✓	Spotted Towhee
		Sharp-shinned Hawk
	✓	Swainson's Thrush
		Sandhill Crane
	✓	Tree Swallow
		Turkey Vulture
		Upland Sandpiper
	✓	Vesper Sparrow
	✓	Violet-green Swallow
✓	✓	Warbling Vireo
	✓	Western Kingbird
✓	✓	Western Meadowlark
✓	✓	Western Wood-pewee
	✓	White-breasted Nuthatch
	✓	White-throated Swift
		Wild Turkey
		Wood Duck
		Yellow-bellied Sapsucker
		Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
	✓	Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Yellowstone	**Upstream River Mile**	383.5
Classification	UB: Unconfined braided	**Downstream River Mile**	368.3
General Location	Laurel to Billings	**Length**	15.20 mi (24.46 km)
General Comments	Extensive armoring u/s Billings; WAI Reaches B,C,D		

Narrative Summary

Reach B1, located in Yellowstone County, extends from the mouth of the Clark Fork River to Billings. It is approximately 15.4 miles long, extending from RM 367.0 to 382.4. It is an Unconfined Braided (UB) reach type indicating minimal influence of the valley wall coupled by extensive open gravel bars and low flow channels. Human impacts in Reach B1 include early bridge construction and stream corridor narrowing, flow consolidation through diking and bank armoring, and loss of side channel due to physical blockages and apparent downcutting. Flow alterations in this reach have been substantial; the mean annual flood has dropped an estimated 17 percent due to human influences, and summer low flows have dropped by 42 percent.

In total there are 57,118 feet of bank armor in Reach B1, which equates to 10.82 miles of bank armor in a 15.4 mile long reach of river. Concrete riprap is the most prevalent type of armor, with about 5.5 miles present in 2011, even after the loss of 2,870 feet of concrete armor protection between 2001 and 2011. There are almost four miles of rock riprap, over 4,000 feet of which was constructed since 2001. There are also 7,616 feet of flow deflectors in the reach, and about 2,500 feet of those flow deflectors were built between 2001 and 2011. The most rapid expansion of armor occurred between 1950 and 1995, when the total length of bank protection expanded from 14,872 feet to 47,339 feet.

Numerous bank armor structures have been eroded out in Reach B1. Typically flanked, failed armor was identified at the following locations:
•RM 383L: 330 feet of flow deflectors totally lost
•RM 382.3R: lower 175 feet of concrete riprap flanked
•RM 281.5R: upper 400 feet of concrete riprap flanked: Idled crude oil pipeline is less than 200 feet behind this flanked armor
•RM 380.2R: lower 600 feet of concrete armor flanked
•RM 377.8: upper 540 feet of concrete armor flanked
•RM 373.8R: upper 300 feet and lower 270 feet of concrete armor flanked

The loss of side channel length through time has been extensive. Prior to 1950, almost a mile of side channels had been blocked on the south side of the river at RM 373.8 and at the South Billings Blvd Bridge at RM 371. Since 1950, another 14,800 feet have been blocked by dikes. One major blockage is located about 2 miles upstream of the Duck Creek Bridge at RM 381 and another near the gravel pit/trailer park complex at RM 373. Other side channels have been lost passively, without blockages. In total, Reach B1 has been characterized by a loss of seven miles of side channel length between 1950 and 2001, the majority of which occurred between 1976 and 1996.

A review of available data indicate that the loss of side channels in Reach B1 is both directly and indirectly related to bank stabilization within the reach. Between 1950 and 1976, a series of dikes were constructed upstream of South Billings Blvd to block the course of a primary channel, isolating several thousand feet of channel. Womack (2000) notes that "the greatest measureable change has occurred due to abandonment of secondary channels, primarily due to construction of dikes and secondarily due to channel armoring. A relatively short dike at the upstream end of a braided reach can have a disproportionate effect, because it may effectively eliminate miles of channel". These blockages are associated with some of the braiding parameter reduction in Reach B1. However, the most loss of side channels occurred after 1976, when the dikes above South Billings Blvd. were already in place. Some of these channels were abandoned due to blockage by dikes, and other locations of channel abandonment and braiding parameter reduction show no apparent direct relationship to physical features.

The side channels that were passively abandoned in Reach B1 are commonly perched above the main Yellowstone River channel. This perching indicates that abandonment may be related to downcutting of the main channel. Womack (2000) noted that width to depth ratios decreased in heavily armored reaches due to flow consolidation in a single channel. Womack suggests that channel confinement and consolidation into fewer channels has resulted in downcutting and reduction in width to depth ratio. Flow alterations have also likely contributed to side channel abandonment.

Several bridges were constructed in Reach B1 prior to 1950. These bridges all constrict the natural meander corridor of the river and have been associated with channel downcutting. Womack (2000) showed seven feet of degradation immediately upstream of the South Billings Blvd Bridge.

The primary land use in the reach is non-irrigated agriculture although several thousand acres of agricultural land has been developed since 1950. In 2011, there were about 3,000 acres of land under flood irrigation and 240 acres under pivot in Reach B1. Between 1950 and 2011, the extent of urban/exurban land use expanded from 310 acres to over 2,000 acres. The development has extended into the Channel Migration Zone (CMZ). A total of 810 acres of CMZ are developed, with 242 acres of ground developed for urban/exurban use and 84 acres in pivot irrigation. Another 470 acres of land in the CMZ are under flood irrigation. As a consequence of extensive development in the CMZ, about 25 percent of the total CMZ footprint has become restricted due to armoring and dike construction.

There is one animal handling facility within 300 feet of the north riverbank just downstream of the Duck Creek Bridge at RM 377.7.

A total of 610 acres of the historic 100-year floodplain has become isolated from the river, which is 14 percent of the total 100-year floodplain footprint. Most of the 100-year floodplain isolation is due to transportation infrastructure. Similarly, about 13 percent of the 5-year floodplain (270 acres) has been isolated by transportation infrastructure. There are 184 acres of flood irrigated land in the 5-year floodplain, and 73 acres in pivot. Whereas most of the isolated 100-year floodplain area is behind the I-90 corridor in the city of Billings, most of the isolated 5-year area is in the stream corridor, which supports the interpretation that some downcutting in the reach has perched historic channels and floodplain area.

There are several pipeline crossings in Reach B1. At RM 382, two pipelines cross under the river; one is a natural gas pipeline owned by NW Energy LLC, and the other is an idled crude oil pipeline owned by Conoco Phillips. The idled crude oil pipeline follows the river close to the bank at RM 281.5R where concrete armor has been flanked. There are four pipelines at South Billings Blvd; the one of these pipelines that was built to carry crude oil has been idled under nitrogen. The other pipelines are all natural gas.

Over 400 acres of wetland have been mapped in the reach, with most of that (270 acres) emergent wetland marsh that is located primarily in the active stream corridor and in abandoned channels. A total of 42 acres of Russian olive have been mapped in the reach, and these trees are dispersed throughout the corridor.

Reach B1 was sampled as part of the avian study. The average species richness in Reach B1 was 8.0, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. One bird Species of Concern (SOC), the Black-Billed Cuckoo, was identified in the reach. Three bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were also found, including the Black and White Warbler, Chimney Swift, and Ovenbird. Since 1950, Reach B1 has lost all of its forest that would be considered at low risk of cowbird infestation due to its separation from agricultural infrastructure. In 1950, about 3.5 acres of forest per valley mile were identified as low risk and by 2001 that forest area had been reduced to zero.

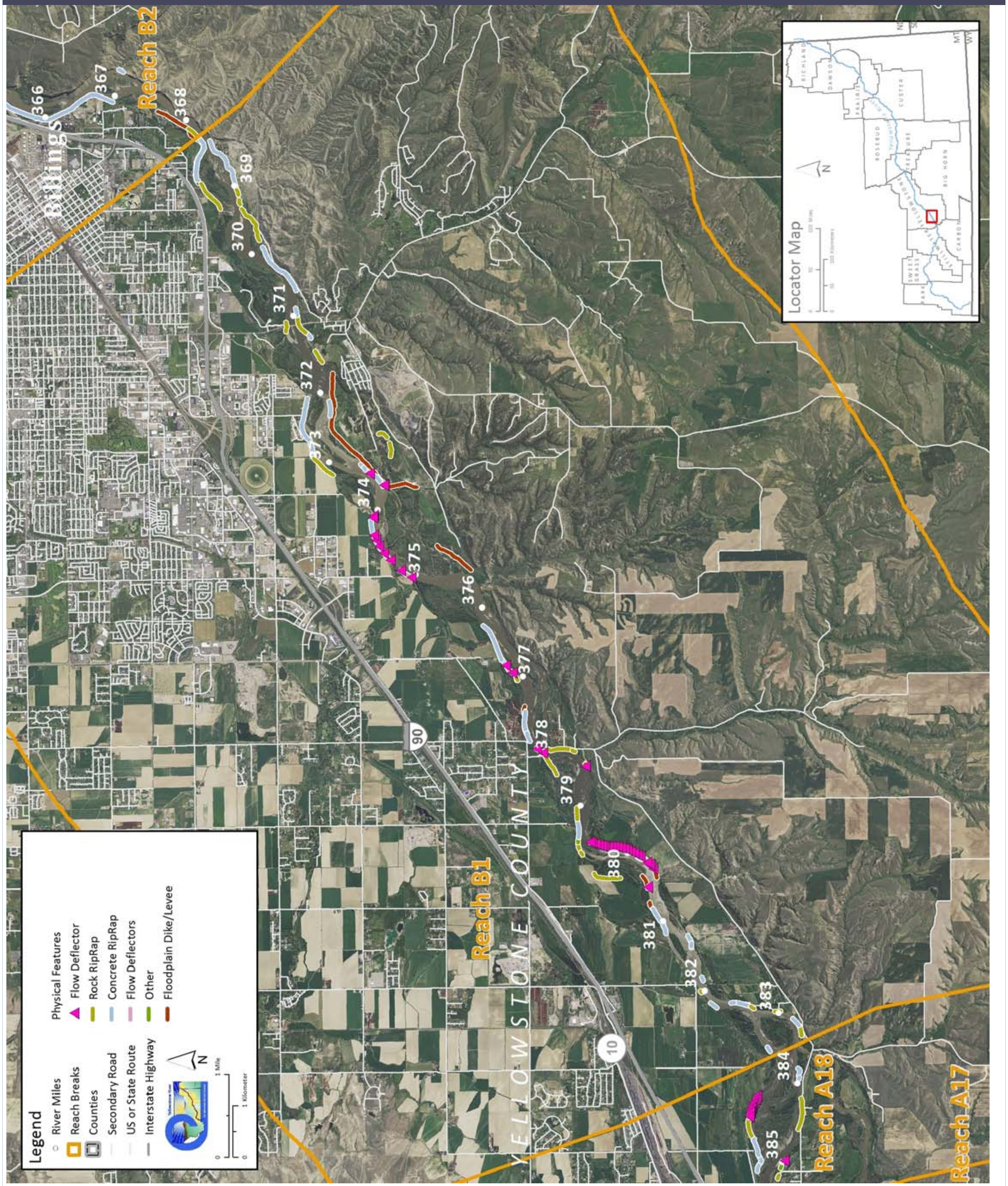
Reach B1 was sampled as part of the fisheries study. A total of 31 fish species were sampled in the reach, and none of these species have been identified by the Montana Natural Heritage Program as Species of Concern (SOC).

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 22,800 cfs to 18,900 cfs, a drop of about 17 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,900 cfs to 2,000 cfs with human development, a reduction of 31 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,836 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B1 include:
•Blockage of miles of side channel
•Extensive armoring with CMZ encroachment
•Passive loss of major side channels due to downcutting and flow alterations

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B1 include:
•Side channel restoration at RM 381 and RM 373
•Pipeline crossing management – natural gas pipeline at RM 382
•Flanked armor removal at RM 383, RM 382.3, RM 281.5, RM 380.2, RM 377.8, and RM 373.8
•CMZ management due to extent of current CMZ restriction (25 percent)
•Russian olive removal
•Pipeline management at crossings and also where concrete armor has flanked where idled crude oil pipeline runs parallel to bank at RM 285.1R
•Nutrient management at corrals that are part of an animal handling facility within 300 feet of river at RM 377.7 just downstream of Duck Creek Bridge.

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	3.9	123.1

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	22,800	42,700	52,800	58,900	71,200	76,200	87,400	2,900	3,846
Regulated	18,900	38,500	48,900	55,200	68,300	73,700	85,900	2,000	2,227
% Change	-17.11%	-9.84%	-7.39%	-6.28%	-4.07%	-3.28%	-1.72%	-31.03%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	5/14/51 - 5/15/51	B/W	1:28,400	6214500	12000
1976	USCOE	28-Sep-76	B/W	1:24,000	6214500	5940
1995	USGS DOQQ	23-Aug-96	B/W		6214500	4500
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	15-May-04	Color	1:15,840	6214500	5960
2005	NAIP	07/12/2005	color	1-meter pixels	6214500	12600
2005	NAIP	07/08/2005	color	1-meter pixels	6214500	11400
2009	NAIP	7/7/2009	Color	1-meter pixels	6214500	20900
2009	NAIP	7/5/2009	Color	1-meter pixels	6214500	23800
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/24/2011	Color	1-meter pixels	6214500	22800
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	16,336	10.1%	20,754	12.9%	4,418
	Flow Deflectors	1,228	0.8%	2,034	1.3%	806
	Concrete RipRap	31,621	19.6%	28,751	17.8%	-2,870
	Car Bodies	942	0.6%	718	0.4%	-225
	Between Flow Deflectors	3,835	2.4%	5,582	3.5%	1,748
	Feature Type Totals	**53,961**	**33.5%**	**57,839**	**35.9%**	**3,877**
Floodplain Control						
	Transportation Encroachment	3,902	2.4%	3,902	2.4%	0
	Floodplain Dike/Levee	23,985	14.9%	23,985	14.9%	0
	Feature Type Totals	**27,887**	**17.3%**	**27,887**	**17.3%**	**0**
	Reach Totals	**81,848**	**50.8%**	**85,726**	**53.2%**	**3,877**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Car Bodies	541	0	400	0	0	0	0	0
Concrete RipRap	7,964	9,719	3,582	951	0	0	0	9,394
Flow Deflectors/Between FDs	4,566	0	328	0	0	0	0	0
Rock RipRap	6,262	0	495	5,169	0	0	0	4,546
Totals	**19,332**	**9,719**	**4,805**	**6,120**	**0**	**0**	**0**	**13,940**

Bankline/Floodplain Inventory: Time Series

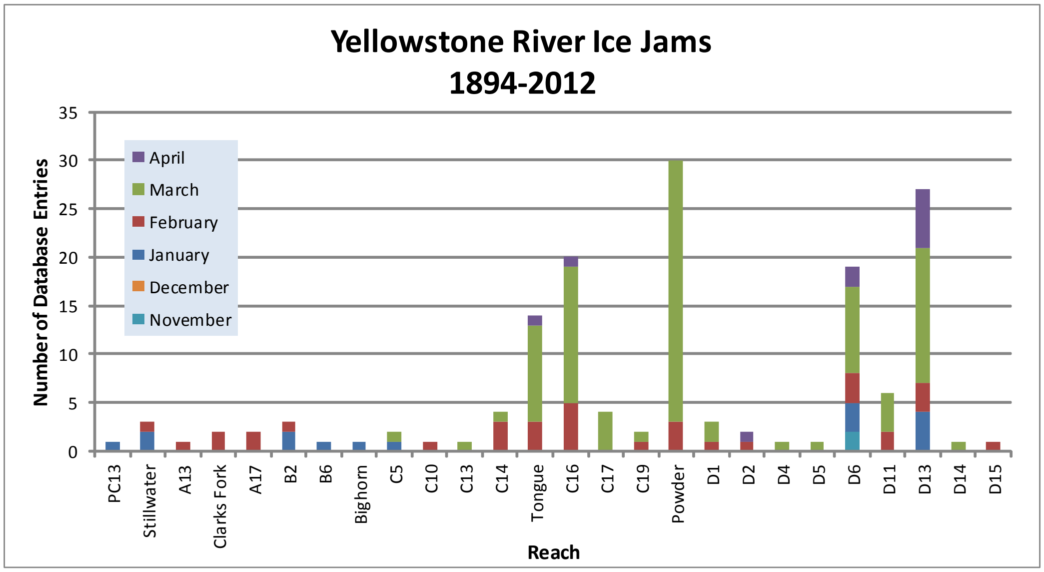
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	103	1,954	1,954	1,954	2,284	2,284
	Totals	**103**	**1,954**	**1,954**	**1,954**	**2,284**	**2,284**
Other							
	Floodplain Dike/Levee	0	0	1,210	1,210	1,210	1,210
	Totals	**0**	**0**	**1,210**	**1,210**	**1,210**	**1,210**
Other Off Channel							
	Floodplain Dike/Levee	0	5,137	12,336	18,261	19,342	19,342
	Floodplain Dike/Levee	4,058	7,900	7,370	19,666	19,666	19,666

	Totals	**4,058**	**13,037**	**19,706**	**37,927**	**39,008**	**39,008**
Stream Stabilization							
	Rock RipRap	7,373	18,198	19,335	19,832	22,285	22,285
	Flow Deflector	1,589	914	914	6,024	6,024	6,024
	Concrete RipRap	5,569	16,943	25,910	31,257	31,544	31,544
	Car Bodies	341	1,039	1,180	1,180	1,180	1,180
	Totals	**14,872**	**37,094**	**47,339**	**58,293**	**61,033**	**61,033**
Transportation Encroachment							
	Other	11,368	14,402	15,081	15,295	15,295	15,295
	Interstate	0	7,583	7,583	7,583	7,583	7,583
	County Road	9,792	17,180	15,814	15,814	15,814	15,814
	Bridge Approach	3,230	5,909	5,909	5,909	5,909	5,909
	Totals	**24,390**	**45,075**	**44,387**	**44,601**	**44,601**	**44,601**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	79,617	120,036	2.51	1950 to 1976:	-3.18%
1976	77,560	110,757	2.43	1976 to 1995:	-18.58%
1995	81,942	80,054	1.98	1995 to 2001:	2.88%
2001	80,555	83,280	2.03	1950 to 2001:	-18.90%
Change 1950 - 2001	**938**	**-36,757**	**-0.47**		

Length of Side Channels Blocked

Pre-1950s (ft)	4,970
Post-1950s (ft)	14,812

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	11	0.2%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	600	13.3%		
Total Not Isolated (Ac)	3899		3470	
Total Floodplain Area (Ac)	4509		3737	
Total Isolated (Ac)	**611**	**13.5%**	**267**	**13.1%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	184	3	73	**260**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
362	724	4,742	1,192	25%	355	91	26%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Other Infrastructure	6	0.1%
	Non-Irrigated	28	0.5%
RipRap/Flow Deflectors			
	Irrigated	192	3.8%
RipRap			
	Public Road	178	3.5%
	Other Infrastructure	35	0.7%
	Non-Irrigated	227	4.5%
	Irrigated	142	2.8%
	Exurban Residential	52	1.0%
	Canal	10	0.2%
Dike/Levee			
	Non-Irrigated	416	8.1%
	Totals	**1,285**	**25.2%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
466.6	0.0	83.9	241.9	16.5

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	21	21	21	21	0.2%	0.2%	0.2%	0.2%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	200	222	294	333	1.5%	1.7%	2.3%	2.6%
	Totals	**221**	**243**	**316**	**354**	**1.7%**	**1.9%**	**2.4%**	**2.7%**
Agricultural Land									
	Non-Irrigated	6,549	5,213	4,985	4,742	50.3%	40.1%	38.3%	36.5%
	Irrigated	2,905	3,060	3,637	3,190	22.3%	23.5%	28.0%	24.5%
	Totals	**9,454**	**8,273**	**8,623**	**7,931**	**72.7%**	**63.6%**	**66.3%**	**61.0%**
Channel									
	Channel	2,913	3,120	2,221	2,318	22.4%	24.0%	17.1%	17.8%
	Totals	**2,913**	**3,120**	**2,221**	**2,318**	**22.4%**	**24.0%**	**17.1%**	**17.8%**
ExUrban									
	ExUrban Other	0	6	107	125	0.0%	0.0%	0.8%	1.0%
	ExUrban Undeveloped	10	17	27	22	0.1%	0.1%	0.2%	0.2%
	ExUrban Industrial	3	65	107	194	0.0%	0.5%	0.8%	1.5%
	ExUrban Commercial	0	0	0	7	0.0%	0.0%	0.0%	0.1%
	ExUrban Residential	129	240	302	362	1.0%	1.8%	2.3%	2.8%
	Totals	**142**	**328**	**544**	**710**	**1.1%**	**2.5%**	**4.2%**	**5.5%**
Transportation									
	Public Road	102	94	98	103	0.8%	0.7%	0.8%	0.8%
	Interstate	0	48	48	48	0.0%	0.4%	0.4%	0.4%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**102**	**141**	**145**	**151**	**0.8%**	**1.1%**	**1.1%**	**1.2%**
Urban									
	Urban Other	0	23	25	25	0.0%	0.2%	0.2%	0.2%
	Urban Residential	148	608	876	1,020	1.1%	4.7%	6.7%	7.8%
	Urban Commercial	0	14	16	19	0.0%	0.1%	0.1%	0.1%
	Urban Undeveloped	0	134	100	109	0.0%	1.0%	0.8%	0.8%
	Urban Industrial	27	123	142	369	0.2%	0.9%	1.1%	2.8%
	Totals	**175**	**902**	**1,159**	**1,542**	**1.3%**	**6.9%**	**8.9%**	**11.9%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	26	26	0.0%	0.0%	0.3%	0.3%	0.0%	0.3%	0.0%	0.3%
	Pivot	0	0	192	241	0.0%	0.0%	2.2%	3.0%	0.0%	2.2%	0.8%	3.0%
	Flood	2,905	3,060	3,420	2,922	30.7%	37.0%	39.7%	36.8%	6.3%	2.7%	-2.8%	6.1%
	Totals	**2,905**	**3,060**	**3,637**	**3,190**	**30.7%**	**37.0%**	**42.2%**	**40.2%**	**6.3%**	**5.2%**	**-2.0%**	**9.5%**

Non-Irrigated													
Multi-Use	3,762	3,367	4,503	4,089	39.8%	40.7%	52.2%	51.6%	0.9%	11.5%	-0.7%	11.8%
Hay/Pasture	2,787	1,846	482	653	29.5%	22.3%	5.6%	8.2%	-7.2%	-16.7%	2.6%	-21.2%
Totals	**6,549**	**5,213**	**4,985**	**4,742**	**69.3%**	**63.0%**	**57.8%**	**59.8%**	**-6.3%**	**-5.2%**	**2.0%**	**-9.5%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.9	0.4	0.5	0.4	0.2	0.8	1.9	1.1	0.0
Max	44.3	211.9	49.8	97.4	139.8	253.9	132.1	43.4	168.8
Average	11.5	12.8	12.8	27.4	20.1	34.6	25.3	15.1	17.8
Sum	402.4	539.4	500.4	1,262.6	1,367.5	1,385.2	556.9	272.5	446.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	509.3
Channel to Riparian (acres)	718.4
Riparian Encroachment (acres)	**209.1**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	763.3
1950s Floodplain Mapped as 2011 Channel (Ac)	185.9
Total Recruitment (1950s to 2011)(Ac)	**949.2**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	81.4	269.3	70.9	0.0	**421.6**
Acres/Valley Mile	6.2	20.4	5.4	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	41.60	1.83%	90.90	8.05	10.44	3.48

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
✓	✓	Bigmouth buffalo
	✓	Black bullhead
✓	✓	Black crappie
		Blue sucker
✓	✓	Bluegill
✓	✓	Brook stickleback
✓	✓	Brown trout
✓	✓	Burbot
		Catfish species
✓	✓	Channel catfish
✓	✓	Common carp
		Creek chub
✓	✓	Emerald shiner
✓	✓	Fathead minnow
✓	✓	Flathead chub
		Freshwater drum
✓	✓	Goldeye
✓	✓	Green sunfish
✓	✓	Lake chub
✓	✓	Largemouth bass
✓	✓	Longnose dace
✓	✓	Longnose sucker
✓	✓	Minnow species
	✓	Mottled sculpin
✓	✓	Mountain sucker
✓	✓	Mountain whitefish
		Northern pike
		Northern plains killifish
		Northern redbelly dace
		Pallid sturgeon
✓	✓	Pumpkinseed
✓	✓	Rainbow trout
✓	✓	River carpsucker
		Rock bass
	✓	Sand shiner
	✓	Sauger
✓	✓	Shorthead redhorse
		Shortnose gar
		Shovelnose sturgeon
		Sicklefin chub
✓	✓	Smallmouth bass
		Smallmouth buffalo
✓	✓	Stonecat
		Sturgeon chub
✓	✓	Sucker species
✓	✓	Sunfish species
		Walleye
✓	✓	Western silvery minnow
		White bass
✓	✓	White crappie
✓	✓	White sucker
		Yellow bullhead
	✓	Yellow perch

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	256.7	146.5	6.6%
Rip Rap Bottom	319.3	143.7	6.5%
Rip Rap Margin	191.5	100.1	4.5%
Bluff Pool	15.4	5.2	0.2%
Terrace Pool	34.6	35.2	1.6%
Secondary Channel	149.0	64.9	2.9%
Secondary Channel (Seasonal)	436.3	259.2	11.7%
Channel Crossover	259.7	175.9	7.9%
Point Bar		131.6	5.9%
Side Bar		86.8	3.9%
Mid-channel Bar		153.1	6.9%
Island	558.6	562.1	25.3%
Dry Channel		356.9	16.1%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern   Potential Species of Concern

Reach	Region	Species
✓	✓	American Robin
	✓	American Crow
✓	✓	American Goldfinch
		American Kestrel
✓	✓	American Redstart
	✓	Bald Eagle
		Baltimore Oriole
✓	✓	Barn Swallow
	✓	Belted Kingfisher
✓	✓	Black-billed Cuckoo
✓	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
✓	✓	Black-and-white Warbler
✓	✓	Black-headed Grosbeak
	✓	Blue Jay
		Bobolink
✓	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
		Brown Creeper
✓	✓	Brown Thrasher
✓	✓	Bullock's Oriole
✓	✓	Canada Goose
✓	✓	Cedar Waxwing
✓	✓	Chimney Swift
	✓	Chipping Sparrow
	✓	Clay-collared Sparrow
		Cliff Swallow
✓	✓	Common Grackle
		Common Merganser
		Common Nighthawk
	✓	Common Raven
✓	✓	Common Yellowthroat
		Cooper's Hawk
	✓	Dickcissel
✓	✓	Downy Woodpecker
		Eastern Bluebird
✓	✓	Eastern Kingbird
		Eurasian Collared-dove
✓	✓	European Starling
✓	✓	Field Sparrow
		Franklin's Gull
		Grasshopper Sparrow
✓	✓	Gray Catbird
		Great Blue Heron
		Great Horned Owl
✓	✓	Hairy Woodpecker
✓	✓	House Finch
✓	✓	House Wren
		Killdeer
		Lark Bunting
	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
✓	✓	Mallard
		Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
		Orchard Oriole
✓	✓	Osprey
✓	✓	Ovenbird
✓	✓	Plumbeous Vireo
	✓	Red-headed Woodpecker
		Red-naped Sapsucker
		Red Crossbill
✓	✓	Ring-necked Pheasant
✓	✓	Red-tailed hawk
✓	✓	Rock Dove
✓	✓	Red-winged Blackbird
✓	✓	Red-eyed Vireo
		Red-breasted Grosbeak
		Say's Phoebe
✓	✓	Savannah Sparrow
✓	✓	Song Sparrow
✓	✓	Spotted Sandpiper
✓	✓	Spotted Towhee
		Sharp-shinned Hawk
✓	✓	Swainson's Thrush
		Sandhill Crane
✓	✓	Tree Swallow
		Turkey Vulture
		Upland Sandpiper
✓	✓	Vesper Sparrow
✓	✓	Violet-green Swallow
✓	✓	Warbling Vireo
	✓	Western Kingbird
	✓	Western Meadowlark
✓	✓	Western Wood-pewee
✓	✓	White-breasted Nuthatch
	✓	White-throated Swift
		Wild Turkey
✓	✓	Wood Duck
		Yellow-bellied Sapsucker
		Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
		Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Yellowstone	**Upstream River Mile**	368.3
Classification	PCB: Partially confined braided	**Downstream River Mile**	362.2
General Location	Billlings	**Length**	6.10 mi (9.82 km)
General Comments	Billlings; WAI Reach E		

Narrative Summary

Reach B2 is 6.1 miles long and located in Billings. The reach extends from the rimrock bluffs south of town, under the I-90 Bridge, to the refinery area at Lockwood. It is a Partially Confined Braided (PCB) reach type indicating some influence of the bluff line on the river coupled by extensive open gravel bars and low flow channels. Reach B2 is extensively urbanized, with floodplain dikes, industrial and urban/exurban development, pipeline crossings, and bridges throughout the reach. Flow alterations in this reach have been substantial; the mean annual flood has dropped an estimated 17 percent due to human influences, and summer low flows have dropped by 42 percent.

In total there are 21,700 feet of bank armor in Reach B2, which equates to 4.1 miles of bank armor in a 6 mile long reach of river. Concrete riprap is the most prevalent type of armor, with about three miles present in 2011. There is almost a mile of rock riprap and a few flow deflectors. There are also over three miles of floodplain dikes mapped in the reach.

Since 1950, 6,566 feet of side channels have been blocked by dikes. These blocked side channels are in highly urbanized areas upstream of the I-90 Bridge and at the water treatment plant downstream.

The primary land use in the reach is urban/exurban development. A total of 620 acres of the historic 100-year floodplain has become isolated from the river, which is 41 percent of the total 100-year floodplain footprint. Most of the 100-year floodplain isolation is due to the Interstate Highway Embankment. Approximately 21 percent of the Channel Migration Zone has become restricted due to physical features, most of which are riprap installed to protect urban/industrial land uses.

A total of three ice jams have been recorded in Reach B2. One of these jams occurred in February of 1996, and the other two in January of 1997. They all resulted in flooding and the January 3 1997 jam caused some evacuations. The jams were reported as forming upstream of the I-90 Bridge.

There are numerous pipeline crossings in Reach B2. At RM 367 two pipelines cross under the river. One is a crude oil pipeline owned by Beartooth Pipeline that is HDD (Horizontal Directionally Drilled). The other is a petroleum product pipeline owned by Phillips 66 that as of Fall 2012 was trenched, and according to the addendum to the Yellowstone River Pipeline Risk Assessment, had 4 to 10 feet of cover. Further downstream, there are seven pipelines listed in the Pipeline Risk Assessment Report at RM 365. Several of these pipelines are trenched as a bundle, with a reported minimum of two feet of cover.
About 25 acres of Russian olive have been mapped in Reach B2.

Reach B2 was sampled as part of the fisheries study. A total of 31 fish species were sampled in the reach and one of those species was Sauger, which has been identified by the Montana Natural Heritage Program as a Species of Concern (SOC).

Reach B2 was sampled as part of the avian study. The average species richness in Reach B2 was 7.0, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. Two bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were also found, the Ovenbird and the Plumbeous Vireo.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 23,700 cfs to 19,700 cfs, a drop of about 17 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,910 cfs to 2,000 cfs with human development, a reduction of 31 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,836 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B2 include:
•Extensive armoring with CMZ encroachment

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B2 include:
•Pipeline crossing management
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	178.2	-3.9

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	23,700	44,200	54,500	60,800	73,500	78,600	90,100	2,910	3,846
Regulated	19,700	39,800	50,400	57,000	70,500	76,000	88,500	2,000	2,227
% Change	-16.88%	-9.95%	-7.52%	-6.25%	-4.08%	-3.31%	-1.78%	-31.27%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	5/15/1951 - 5/14/51	B/W	1:28,400	6214500	12000
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	23-Aug-96	B/W		6214500	4500
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	15-May-04	Color	1:15,840	6214500	5960
2005	NAIP	07/12/2005	color	1-meter pixels	6214500	12600
2005	NAIP	07/08/2005	color	1-meter pixels	6214500	11400
2009	NAIP	7/5/2009	Color	1-meter pixels	6214500	23800
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/24/2011	Color	1-meter pixels	6214500	22800
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Steel Retaining Wall	192	0.3%	192	0.3%	0
	Rock RipRap	3,501	5.4%	4,329	6.7%	828
	Flow Deflectors	0	0.0%	67	0.1%	67
	Concrete RipRap	17,283	26.8%	17,283	26.8%	0
	Between Flow Deflectors	0	0.0%	24	0.0%	24
	Feature Type Totals	**20,977**	**32.5%**	**21,895**	**34.0%**	**918**
Other In Channel						
	Bedrock Outcrop	208	0.3%	208	0.3%	0
	Feature Type Totals	**208**	**0.3%**	**208**	**0.3%**	**0**
Floodplain Control						
	Floodplain Dike/Levee	7,037	10.9%	7,037	10.9%	0
	Feature Type Totals	**7,037**	**10.9%**	**7,037**	**10.9%**	**0**
	Reach Totals	**28,223**	**43.8%**	**29,141**	**45.2%**	**918**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	0	315	2,647	328	656	328	13,002	0
Rock RipRap	689	928	0	0	715	0	1,217	0
Steel Retaining Wall	0	0	0	0	0	0	194	0
Totals	**689**	**1,243**	**2,647**	**328**	**1,371**	**328**	**14,412**	**0**

Bankline/Floodplain Inventory: Time Series

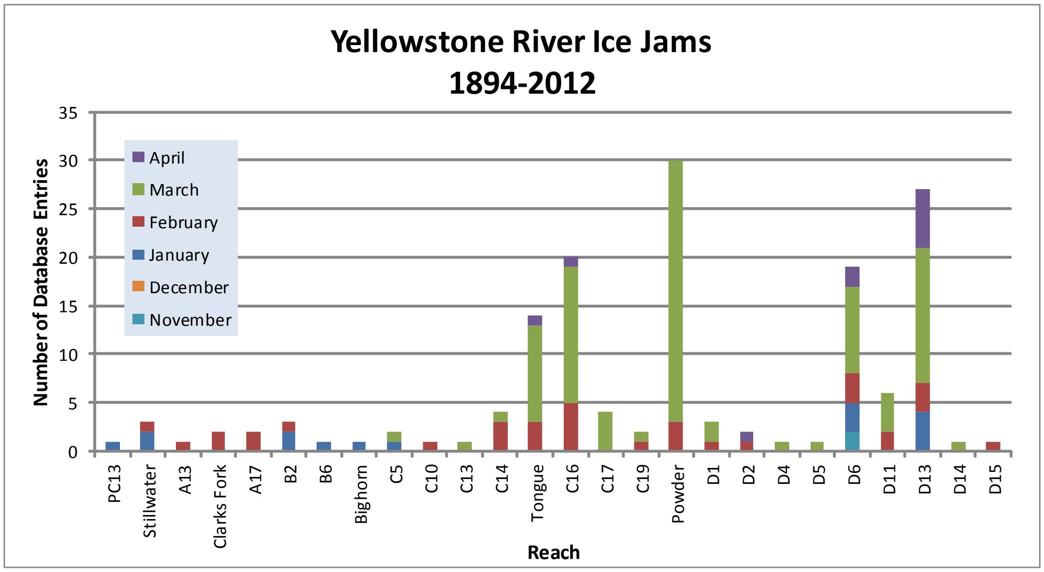
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	5,400	5,400	5,400	5,400	5,400	5,400
	Totals	**5,400**	**5,400**	**5,400**	**5,400**	**5,400**	**5,400**
Other							
	Floodplain Dike/Levee	12,435	17,523	17,523	17,523	17,523	17,523
	Totals	**12,435**	**17,523**	**17,523**	**17,523**	**17,523**	**17,523**
Other Off Channel							
	Floodplain Dike/Levee	0	3,468	3,468	3,468	3,468	3,468

Floodplain Dike/Levee	0	0	757	757	757	757
Totals	**0**	**3,468**	**4,225**	**4,225**	**4,225**	**4,225**
Stream Stabilization						
Steel Retaining Wall	275	275	275	275	275	275
Rock RipRap	1,100	2,973	3,758	3,758	3,758	3,758
Concrete RipRap	5,062	15,933	18,005	18,005	18,005	18,005
Totals	**6,437**	**19,182**	**22,039**	**22,039**	**22,039**	**22,039**
Transportation Encroachment						
Railroad	1,491	1,491	1,491	1,491	1,491	1,491
Other	3,322	3,960	1,861	1,861	1,861	1,861
Interstate	0	10,378	10,378	10,378	10,378	10,378
County Road	6,101	8,904	8,904	8,904	8,904	8,904
Totals	**10,913**	**24,732**	**22,633**	**22,633**	**22,633**	**22,633**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
2/6/1996	NA	366	Flooded roadways
1/3/1997	NA	366	Flooding, evacuations
1/10/1997	NA	366	?

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	31,111	29,288	1.94
1976	31,620	31,888	2.01
1995	32,440	24,341	1.75
2001	32,233	24,867	1.77
Change 1950 - 2001	**1,123**	**-4,421**	**-0.17**

	% Change in Braiding
1950 to 1976:	3.45%
1976 to 1995:	-12.85%
1995 to 2001:	1.21%
1950 to 2001:	-8.75%

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	6,566

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	50	3.3%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	570	37.9%		
Total Not Isolated (Ac)	884		852	
Total Floodplain Area (Ac)	1504		910	
Total Isolated (Ac)	**620**	**41.2%**	**58**	**15.4%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	0	**0**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
245	490	1,118	251	22%	66	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Urban Industrial	218	18.2%
Dike/Levee			
	Exurban Other	38	3.1%
	Totals	**256**	**21.3%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
0.0	0.0	0.0	276.5	10.3

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	33	17	9	17	0.8%	0.4%	0.2%	0.4%
	Totals	**33**	**17**	**9**	**17**	**0.8%**	**0.4%**	**0.2%**	**0.4%**
Agricultural Land									
	Non-Irrigated	1,988	1,545	1,358	1,066	45.8%	35.6%	31.3%	24.6%
	Irrigated	469	25	5	5	10.8%	0.6%	0.1%	0.1%
	Totals	**2,457**	**1,569**	**1,363**	**1,071**	**56.6%**	**36.2%**	**31.4%**	**24.7%**
Channel									
	Channel	725	702	612	629	16.7%	16.2%	14.1%	14.5%
	Totals	**725**	**702**	**612**	**629**	**16.7%**	**16.2%**	**14.1%**	**14.5%**
ExUrban									
	ExUrban Other	138	0	0	0	3.2%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	5	0	0	0	0.1%	0.0%	0.0%	0.0%
	ExUrban Industrial	30	0	0	0	0.7%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	145	15	0	0	3.3%	0.3%	0.0%	0.0%
	Totals	**318**	**15**	**0**	**0**	**7.3%**	**0.3%**	**0.0%**	**0.0%**
Transportation									
	Public Road	29	32	32	32	0.7%	0.7%	0.7%	0.7%
	Interstate	0	79	80	80	0.0%	1.8%	1.8%	1.8%
	Railroad	17	17	17	17	0.4%	0.4%	0.4%	0.4%
	Totals	**46**	**128**	**128**	**128**	**1.1%**	**2.9%**	**2.9%**	**2.9%**
Urban									
	Urban Other	13	58	90	98	0.3%	1.3%	2.1%	2.3%
	Urban Residential	117	455	472	713	2.7%	10.5%	10.9%	16.4%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	111	91	54	0.0%	2.6%	2.1%	1.2%
	Urban Industrial	630	1,285	1,575	1,631	14.5%	29.6%	36.3%	37.6%
	Totals	**760**	**1,910**	**2,228**	**2,495**	**17.5%**	**44.0%**	**51.3%**	**57.5%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	5	5	0.0%	0.0%	0.4%	0.5%	0.0%	0.4%	0.1%	0.5%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	469	25	0	0	19.1%	1.6%	0.0%	0.0%	-17.5%	-1.6%	0.0%	-19.1%
	Totals	**469**	**25**	**5**	**5**	**19.1%**	**1.6%**	**0.4%**	**0.5%**	**-17.5%**	**-1.2%**	**0.1%**	**-18.6%**

Non-Irrigated													
Multi-Use	1,157	427	1,138	939	47.1%	27.2%	83.5%	87.6%	-19.8%	56.3%	4.1%	40.5%
Hay/Pasture	832	1,117	219	127	33.8%	71.2%	16.1%	11.9%	37.4%	-55.1%	-4.2%	-22.0%
Totals	**1,988**	**1,545**	**1,358**	**1,066**	**80.9%**	**98.4%**	**99.6%**	**99.5%**	**17.5%**	**1.2%**	**-0.1%**	**18.6%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	1.9	0.3	1.1	3.0	0.8	1.9	6.1	8.1	11.8
Max	87.6	41.0	40.7	59.3	90.7	125.5	87.3	58.1	43.3
Average	16.4	9.5	7.2	17.5	13.4	25.8	35.5	31.4	24.7
Sum	180.6	94.7	65.0	210.2	255.2	361.8	248.4	157.1	98.9

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	129.1
Channel to Riparian (acres)	91.8
Riparian Encroachment (acres)	**-37.2**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	105.2
1950s Floodplain Mapped as 2011 Channel (Ac)	42.7
Total Recruitment (1950s to 2011)(Ac)	**147.9**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	44.5	19.6	11.6	0.0	**75.7**
Acres/Valley Mile	8.0	3.5	2.1	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	24.62	3.18%	40.06	2.32	5.89	3.52

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
	✓	Bigmouth buffalo
✓	✓	Black bullhead
✓	✓	Black crappie
		Blue sucker
✓	✓	Bluegill
✓	✓	Brook stickleback
✓	✓	Brown trout
✓	✓	Burbot
		Catfish species
✓	✓	Channel catfish
✓	✓	Common carp
		Creek chub
✓	✓	Emerald shiner
✓	✓	Fathead minnow
✓	✓	Flathead chub
		Freshwater drum
✓	✓	Goldeye
✓	✓	Green sunfish
✓	✓	Lake chub
✓	✓	Largemouth bass
✓	✓	Longnose dace
✓	✓	Longnose sucker
	✓	Minnow species
	✓	Mottled sculpin
✓	✓	Mountain sucker
✓	✓	Mountain whitefish
		Northern pike
		Northern plains killifish
		Northern redbelly dace
		Pallid sturgeon
✓	✓	Pumpkinseed
✓	✓	Rainbow trout
✓	✓	River carpsucker
		Rock bass
✓	✓	Sand shiner
✓	✓	Sauger
✓	✓	Shorthead redhorse
		Shortnose gar
		Shovelnose sturgeon
		Sicklefin chub
✓	✓	Smallmouth bass
		Smallmouth buffalo
✓	✓	Stonecat
		Sturgeon chub
✓	✓	Sucker species
	✓	Sunfish species
		Walleye
✓	✓	Western silvery minnow
		White bass
✓	✓	White crappie
✓	✓	White sucker
		Yellow bullhead
	✓	Yellow perch

Low Flow Fisheries Habitat Mapping

2001 (Acres)

Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	59.0	20.9	3.4%
Rip Rap Bottom	92.6	67.5	11.0%
Rip Rap Margin	19.4	11.8	1.9%
Bluff Pool	104.4	86.8	14.2%
Secondary Channel	10.3	16.5	2.7%
Secondary Channel (Seasonal)	132.4	90.6	14.8%
Channel Crossover	112.2	69.6	11.4%
Point Bar		15.4	2.5%
Side Bar		27.5	4.5%
Mid-channel Bar		27.3	4.5%
Island	81.5	81.5	13.3%
Dry Channel		96.2	15.7%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern

Potential Species of Concern

Reach	Region	Species
✔	✔	American Robin
	✔	American Crow
✔	✔	American Goldfinch
		American Kestrel
✔	✔	American Redstart
	✔	Bald Eagle
		Baltimore Oriole
	✔	Barn Swallow
	✔	Belted Kingfisher
	✔	Black-billed Cuckoo
✔	✔	Black-billed Magpie
✔	✔	Black-capped Chickadee
	✔	Black-and-white Warbler
✔	✔	Black-headed Grosbeak
	✔	Blue Jay
		Bobolink
	✔	Brewer's Blackbird
✔	✔	Brown-headed Cowbird
		Brown Creeper
✔	✔	Brown Thrasher
✔	✔	Bullock's Oriole
	✔	Canada Goose
✔	✔	Cedar Waxwing
	✔	Chimney Swift
	✔	Chipping Sparrow
	✔	Clay-collared Sparrow
		Cliff Swallow
✔	✔	Common Grackle
		Common Merganser
		Common Nighthawk
	✔	Common Raven
✔	✔	Common Yellowthroat
		Cooper's Hawk
	✔	Dickcissel
✔	✔	Downy Woodpecker
		Eastern Bluebird
✔	✔	Eastern Kingbird
		Eurasian Collared-dove
✔	✔	European Starling
✔	✔	Field Sparrow
		Franklin's Gull
		Grasshopper Sparrow
✔	✔	Gray Catbird
		Great Blue Heron
		Great Horned Owl
✔	✔	Hairy Woodpecker
	✔	House Finch
✔	✔	House Wren
		Killdeer
		Lark Bunting
	✔	Lark Sparrow
✔	✔	Lazuli Bunting
✔	✔	Least Flycatcher
	✔	Mallard
		Mountain Bluebird
✔	✔	Mourning Dove
✔	✔	Northern Flicker
		Orchard Oriole
	✔	Osprey
✔	✔	Ovenbird
✔	✔	Plumbeous Vireo
	✔	Red-headed Woodpecker
		Red-naped Sapsucker
		Red Crossbill
	✔	Ring-necked Pheasant
	✔	Red-tailed hawk
	✔	Rock Dove
✔	✔	Red-winged Blackbird
✔	✔	Red-eyed Vireo
		Red-breasted Grosbeak
		Say's Phoebe
	✔	Savannah Sparrow
✔	✔	Song Sparrow
	✔	Spotted Sandpiper
✔	✔	Spotted Towhee
		Sharp-shinned Hawk
	✔	Swainson's Thrush
		Sandhill Crane
✔	✔	Tree Swallow
		Turkey Vulture
		Upland Sandpiper
	✔	Vesper Sparrow
	✔	Violet-green Swallow
	✔	Warbling Vireo
	✔	Western Kingbird
	✔	Western Meadowlark
✔	✔	Western Wood-pewee
	✔	White-breasted Nuthatch
	✔	White-throated Swift
		Wild Turkey
	✔	Wood Duck
		Yellow-bellied Sapsucker
		Yellow-billed Cuckoo
✔	✔	Yellow-breasted Chat
		Yellow-headed Blackbird
✔	✔	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Yellowstone	**Upstream River Mile**	362.2
Classification	UB: Unconfined braided	**Downstream River Mile**	357.9
General Location	East Billings	**Length**	4.30 mi (6.92 km)
General Comments	Wide corridor d/s Billings; WAI Reach F		

Narrative Summary

Reach B3 is 4.3 miles long and located in east Billings. The reach is characterized by the loss of several miles of side channel, extensive Russian olive infestation, and substantial flow alterations due to human influences.

In total there are about 13,500 feet of bank armor in Reach B3, which covers almost 30 percent of the bankline. Most of the armor is rock riprap, although there are over 3,000 feet of flow deflectors mapped in the reach, as well as over a mile of floodplain dikes.

Prior to 1950, 11,000 feet of side channels had been blocked in the reach, and since that time another 14,000 feet have been similarly blocked by small dikes. These ~4 miles of blocked channel are about equivalent in length to that of the main river. That said, as of 2001 there were still about 35,000 feet of active side channel in Reach B3.

Solid waste dumps were mapped on old side channels on the east floodplain areas at RM 361.5 and RM 360.6. There is one major headgate on the left bank of the river that feeds a heavily armored canal at RM 359.9.

Flow alterations and channel blockages have promoted the encroachment of riparian vegetation into old channel areas. Since 1950, almost 200 acres of riparian vegetation colonized previously un-vegetated side channels. Floodplain turnover rates have gone down since 1976 by about 2 acres per year, indicating slower rates of erosion.

Since 1950, predominantly agricultural land uses in Reach B3 have been converted to a mix of agriculture and urban/exurban development. About 1,000 acres of urban/exurban development has taken place since 1950. About 470 acres of ground continues to be flood irrigated in this area of east Billings. Approximately 16 percent of the Channel Migration Zone has become restricted due to physical features, all of which are bank armor installations designed to protect urban/industrial and agricultural land uses.

About 50 acres of Russian olive have been mapped in Reach B3. There are also fairly extensive mapped wetlands, with about 230 acres of total wetland area mapped, 95 acres of which are emergent wet meadows and marsh areas.

Reach B3 was sampled as part of the fisheries study. A total of 29 fish species were sampled in the reach, and none of those species have been identified by the Montana Natural Heritage Program as a Species of Concern (SOC).

Reach B3 was sampled as part of the avian study. The average species richness in this reach was 7.5, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. One bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) was also found, the Plumbeous Vireo.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 23,900 cfs to 19,800 cfs, a drop of about 17 percent. The 2-year flood, which strongly influences overall channel form, has dropped from 44,500 cfs to 40,100 cfs, which is a reduction of 10 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,920 cfs to 2,010 cfs with human development, a reduction of 31 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,836 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B3 include:
•Riparian encroachment with flow alterations
Extensive armoring with CMZ encroachment

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B3 include:
•Side channel reactivation at RM 362.0, 360.5, 359.8 and RM 359.0
•Russian olive removal
•Solid waste dump removal RM 361.5 and RM 360.6
•Irrigation diversion structure management at RM 359.9.

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	173.9	2.2

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	23,900	44,500	55,000	61,300	74,000	79,200	90,700	2,920	3,846
Regulated	19,800	40,100	50,900	57,500	71,000	76,600	89,100	2,010	2,227
% Change	-17.15%	-9.89%	-7.45%	-6.20%	-4.05%	-3.28%	-1.76%	-31.16%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	14-May-51	B/W	1:28,400	6214500	13200
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	23-Aug-96	B/W		6214500	4500
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	15-May-04	Color	1:15,840	6214500	5960
2005	NAIP	07/08/2005	color	1-meter pixels	6214500	11400
2009	NAIP	7/5/2009	Color	1-meter pixels	6214500	23800
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/24/2011	Color	1-meter pixels	6214500	22800
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	10,299	22.3%	10,047	21.7%	-252
	Flow Deflectors	731	1.6%	772	1.7%	41
	Concrete RipRap	592	1.3%	592	1.3%	0
	Between Flow Deflectors	2,338	5.1%	2,340	5.1%	1
	Feature Type Totals	**13,960**	**30.2%**	**13,751**	**29.7%**	**-209**
Floodplain Control						
	Transportation Encroachment	5,175	11.2%	5,175	11.2%	0
	Floodplain Dike/Levee	5,766	12.5%	5,766	12.5%	0
	Feature Type Totals	**10,941**	**23.7%**	**10,941**	**23.7%**	**0**
	Reach Totals	**24,901**	**53.8%**	**24,692**	**53.4%**	**-209**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	0	98	0	0	0	0	0	886
Flow Deflectors/Between FDs	1,351	0	0	0	0	0	1,535	1,492
Rock RipRap	0	0	0	0	0	0	3,123	0
Totals	**1,351**	**98**	**0**	**0**	**0**	**0**	**4,658**	**2,378**

Bankline/Floodplain Inventory: Time Series

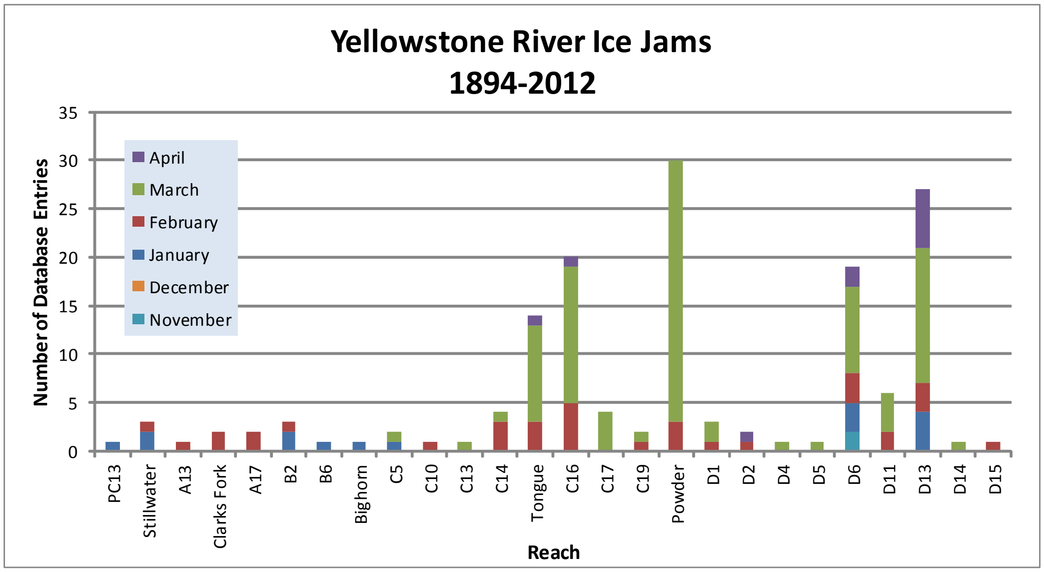
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	6,788	7,002	7,002	7,002	7,002	7,002
	Totals	**6,788**	**7,002**	**7,002**	**7,002**	**7,002**	**7,002**
Other							
	Floodplain Dike/Levee	7,446	7,446	7,446	7,446	7,446	7,446
	Totals	**7,446**	**7,446**	**7,446**	**7,446**	**7,446**	**7,446**
Other Off Channel							
	Floodplain Dike/Levee	0	2,866	6,494	6,494	6,494	6,494
	Floodplain Dike/Levee	155	7,025	9,010	9,010	9,010	9,010
	Totals	**155**	**9,891**	**15,504**	**15,504**	**15,504**	**15,504**
Stream Stabilization							

	Rock RipRap	1,755	6,280	10,177	10,177	10,177	10,177
	Flow Deflector	0	3,244	3,244	3,244	3,244	3,244
	Concrete RipRap	0	0	592	592	592	592
	Totals	**1,755**	**9,524**	**14,012**	**14,012**	**14,012**	**14,012**
Transportation Encroachment							
	Railroad	5,149	5,149	5,149	5,149	5,149	5,149
	Other	303	303	303	3,060	5,072	5,072
	County Road	5,505	5,505	5,505	5,505	5,505	5,505
	Totals	**10,957**	**10,957**	**10,957**	**13,714**	**15,726**	**15,726**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	22,668	41,147	2.82	1950 to 1976:	-21.52%
1976	23,157	28,007	2.21	1976 to 1995:	11.22%
1995	22,999	33,516	2.46	1995 to 2001:	2.60%
2001	23,124	35,173	2.52	1950 to 2001:	-10.45%
Change 1950 - 2001	**456**	**-5,974**	**-0.29**		

Length of Side Channels Blocked

Pre-1950s (ft)	11,002
Post-1950s (ft)	13,693

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1640		1489	
Total Floodplain Area (Ac)	1640		1644	
Total Isolated (Ac)	**0**	**0.0%**	**155**	**14.1%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	76	0	0	**76**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
415	830	1,560	201	13%	64	64	100%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Urban Industrial	105	6.4%
	Irrigated	129	7.9%
RipRap			
	Railroad	32	2.0%
	Totals	**266**	**16.3%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
60.5	0.0	0.0	216.9	5.5

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	50	67	71	51	1.3%	1.8%	1.9%	1.4%
	Totals	**50**	**67**	**71**	**51**	**1.3%**	**1.8%**	**1.9%**	**1.4%**
Agricultural Land									
	Non-Irrigated	2,297	1,703	1,387	1,297	60.5%	44.9%	36.5%	34.2%
	Irrigated	420	703	637	473	11.1%	18.5%	16.8%	12.4%
	Totals	**2,717**	**2,406**	**2,025**	**1,770**	**71.6%**	**63.4%**	**53.3%**	**46.6%**
Channel									
	Channel	870	906	837	853	22.9%	23.9%	22.1%	22.5%
	Totals	**870**	**906**	**837**	**853**	**22.9%**	**23.9%**	**22.1%**	**22.5%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	18	18	332	559	0.5%	0.5%	8.7%	14.7%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	3	14	39	57	0.1%	0.4%	1.0%	1.5%
	Totals	**21**	**32**	**371**	**616**	**0.6%**	**0.8%**	**9.8%**	**16.2%**
Transportation									
	Public Road	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	21	21	20	20	0.6%	0.6%	0.5%	0.5%
	Totals	**21**	**21**	**20**	**20**	**0.6%**	**0.6%**	**0.5%**	**0.5%**
Urban									
	Urban Other	0	0	40	27	0.0%	0.0%	1.1%	0.7%
	Urban Residential	0	96	171	182	0.0%	2.5%	4.5%	4.8%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	12	0	13	0.0%	0.3%	0.0%	0.4%
	Urban Industrial	116	256	261	263	3.1%	6.8%	6.9%	6.9%
	Totals	**116**	**365**	**473**	**485**	**3.1%**	**9.6%**	**12.5%**	**12.8%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	420	703	637	473	15.5%	29.2%	31.5%	26.7%	13.7%	2.3%	-4.8%	11.2%
	Totals	**420**	**703**	**637**	**473**	**15.5%**	**29.2%**	**31.5%**	**26.7%**	**13.7%**	**2.3%**	**-4.8%**	**11.2%**

Non-Irrigated													
	Multi-Use	1,401	1,252	1,137	1,023	51.5%	52.0%	56.2%	57.8%	0.5%	4.1%	1.7%	6.3%
	Hay/Pasture	896	451	250	274	33.0%	18.8%	12.4%	15.5%	-14.2%	-6.4%	3.1%	-17.5%
	Totals	**2,297**	**1,703**	**1,387**	**1,297**	**84.5%**	**70.8%**	**68.5%**	**73.3%**	**-13.7%**	**-2.3%**	**4.8%**	**-11.2%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	4.4	0.5	1.0	1.6	1.4	1.2	0.7	2.6	1.7
Max	74.7	195.9	173.6	147.6	90.2	152.0	91.3	42.9	89.2
Average	29.4	13.8	22.3	29.9	20.3	32.7	20.9	17.8	36.0
Sum	205.9	385.2	356.1	448.2	507.7	523.3	292.9	106.5	179.9

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	156.7
Channel to Riparian (acres)	214.1
Riparian Encroachment (acres)	**57.3**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	216.9
1950s Floodplain Mapped as 2011 Channel (Ac)	138.0
Total Recruitment (1950s to 2011)(Ac)	**355.0**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	95.8	94.9	40.5	0.0	**231.2**
Acres/Valley Mile	25.3	25.0	10.7	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	49.76	4.14%	45.71	7.40	11.57	5.58

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
	✓	Bigmouth buffalo
	✓	Black bullhead
✓	✓	Black crappie
		Blue sucker
✓	✓	Bluegill
✓	✓	Brook stickleback
✓	✓	Brown trout
	✓	Burbot
		Catfish species
✓	✓	Channel catfish
✓	✓	Common carp
		Creek chub
✓	✓	Emerald shiner
✓	✓	Fathead minnow
✓	✓	Flathead chub
		Freshwater drum
✓	✓	Goldeye
✓	✓	Green sunfish
✓	✓	Lake chub
✓	✓	Largemouth bass
✓	✓	Longnose dace
✓	✓	Longnose sucker
	✓	Minnow species
✓	✓	Mottled sculpin
✓	✓	Mountain sucker
✓	✓	Mountain whitefish
		Northern pike
		Northern plains killifish
		Northern redbelly dace
		Pallid sturgeon
✓	✓	Pumpkinseed
✓	✓	Rainbow trout
	✓	River carpsucker
		Rock bass
✓	✓	Sand shiner
	✓	Sauger
✓	✓	Shorthead redhorse
		Shortnose gar
		Shovelnose sturgeon
		Sicklefin chub
✓	✓	Smallmouth bass
		Smallmouth buffalo
✓	✓	Stonecat
		Sturgeon chub
✓	✓	Sucker species
	✓	Sunfish species
		Walleye
✓	✓	Western silvery minnow
		White bass
✓	✓	White crappie
✓	✓	White sucker
		Yellow bullhead
✓	✓	Yellow perch

Low Flow Fisheries Habitat Mapping

2001 (Acres)

Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	48.5	45.2	5.4%
Rip Rap Bottom	95.6	52.8	6.3%
Rip Rap Margin	28.3	13.1	1.6%
Secondary Channel	40.8	15.5	1.8%
Secondary Channel (Seasonal)	211.2	126.3	15.1%
Channel Crossover	116.1	47.6	5.7%
Point Bar		27.0	3.2%
Side Bar		44.3	5.3%
Mid-channel Bar		8.4	1.0%
Island	296.7	296.7	35.4%
Dry Channel		160.1	19.1%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern

Potential Species of Concern

Reach	Region	Species
✓	✓	American Robin
✓	✓	American Crow
✓	✓	American Goldfinch
		American Kestrel
✓	✓	American Redstart
	✓	Bald Eagle
		Baltimore Oriole
✓	✓	Barn Swallow
	✓	Belted Kingfisher
	✓	Black-billed Cuckoo
✓	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
	✓	Black-and-white Warbler
✓	✓	Black-headed Grosbeak
✓	✓	Blue Jay
		Bobolink
	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
		Brown Creeper
	✓	Brown Thrasher
✓	✓	Bullock's Oriole
	✓	Canada Goose
✓	✓	Cedar Waxwing
	✓	Chimney Swift
	✓	Chipping Sparrow
	✓	Clay-collared Sparrow
		Cliff Swallow
✓	✓	Common Grackle
		Common Merganser
		Common Nighthawk
	✓	Common Raven
✓	✓	Common Yellowthroat
		Cooper's Hawk
	✓	Dickcissel
✓	✓	Downy Woodpecker
		Eastern Bluebird
	✓	Eastern Kingbird
		Eurasian Collared-dove
✓	✓	European Starling
✓	✓	Field Sparrow
		Franklin's Gull
		Grasshopper Sparrow
✓	✓	Gray Catbird
		Great Blue Heron
		Great Horned Owl
✓	✓	Hairy Woodpecker
	✓	House Finch
✓	✓	House Wren
		Killdeer
		Lark Bunting
	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
	✓	Mallard
		Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
		Orchard Oriole
	✓	Osprey
	✓	Ovenbird
✓	✓	Plumbeous Vireo
	✓	Red-headed Woodpecker
		Red-naped Sapsucker
		Red Crossbill
	✓	Ring-necked Pheasant
	✓	Red-tailed hawk
	✓	Rock Dove
✓	✓	Red-winged Blackbird
✓	✓	Red-eyed Vireo
		Red-breasted Grosbeak
		Say's Phoebe
✓	✓	Savannah Sparrow
✓	✓	Song Sparrow
	✓	Spotted Sandpiper
✓	✓	Spotted Towhee
		Sharp-shinned Hawk
	✓	Swainson's Thrush
		Sandhill Crane
✓	✓	Tree Swallow
		Turkey Vulture
		Upland Sandpiper
	✓	Vesper Sparrow
✓	✓	Violet-green Swallow
✓	✓	Warbling Vireo
✓	✓	Western Kingbird
	✓	Western Meadowlark
✓	✓	Western Wood-pewee
✓	✓	White-breasted Nuthatch
✓	✓	White-throated Swift
		Wild Turkey
	✓	Wood Duck
		Yellow-bellied Sapsucker
		Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
		Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

Yellowstone River Reach Narratives — Reach B4

County	Yellowstone	**Upstream River Mile**	357.9
Classification	PCS: Partially confined straight	**Downstream River Mile**	354
General Location	Upstream of Huntley	**Length**	3.90 mi (6.28 km)
General Comments	Channel closely follows right valey wall; extensive bank armor		

Narrative Summary

Reach B4 is 3.9 miles long and located upstream of Huntley. It is classified as a Partially Confined Straight (PCS) reach type because within this area the river flows straight along the south valley wall with minimal meandering. The reach is characterized by the most extensive bank armoring of any reach on the river.

In total there are about 29,000 feet of bank protection in Reach B4, such that 74 percent of the bankline is armored. Most of the armor is rock riprap, although there are over 8,000 feet of concrete riprap mapped in the reach, as well as over 9,000 feet of floodplain dikes. Between 2001 and 2011, 500 feet of concrete riprap and 1,050 feet of flow deflectors were eroded out in the reach. The failed flow deflectors and concrete riprap have been largely replaced by rock riprap, although at the upstream end of the reach at RM 357.8, about 300 feet of flanked flow deflectors are in the river about 75 feet off of the left (north) bank.

The predominant land use in the reach is agriculture, with about 1,200 acres of land in flood irrigation in 2011. A total of 204 acres of developed land uses have encroached into the Channel Migration Zone (CMZ), including 193 acres of flood irrigation and 11 acres of transportation corridor. In order to protect these land uses, bank armor installations have isolated about one half of the river's CMZ.

Huntley Diversion Dam is located at RM 355.8. The structure diverts flow into the Huntley Main Canal, which follows the southern margin of the Yellowstone River floodplain. The diversion capacity of Huntley Dam is 600 cfs, and the project has the capacity to provide irrigation water to 30,000 acres of farm land. The crest length of the structure is 325 feet, and its structural height is 10.5 feet (http://www.usbr.gov/dataweb/dams/yellowstone_river_diversion.htm). The Huntley diversion structure was originally constructed as a temporary earthfill dam in 1931. In 1934, the temporary structure was modified to a concrete weir. In 1959, the dam underwent considerable rehabilitation due to undermining caused by settling and cracking of the concrete structure. As part of repairs required after recent flooding on the river, a fish passage channel was constructed around the north end of the dam. The structure is located at a point of split flow on the river, and blocks only the main channel. However, 2001 color infrared air photos of the site show that at low flows, the unblocked secondary channels are essentially dry and therefore incapable of passing fish.

Land has been developed in commonly flooded areas. About 280 acres of flood irrigated land is within the 5-year floodplain area.

There are corrals that are part of an animal handling facility adjacent to the north bank of the river at RM 355.

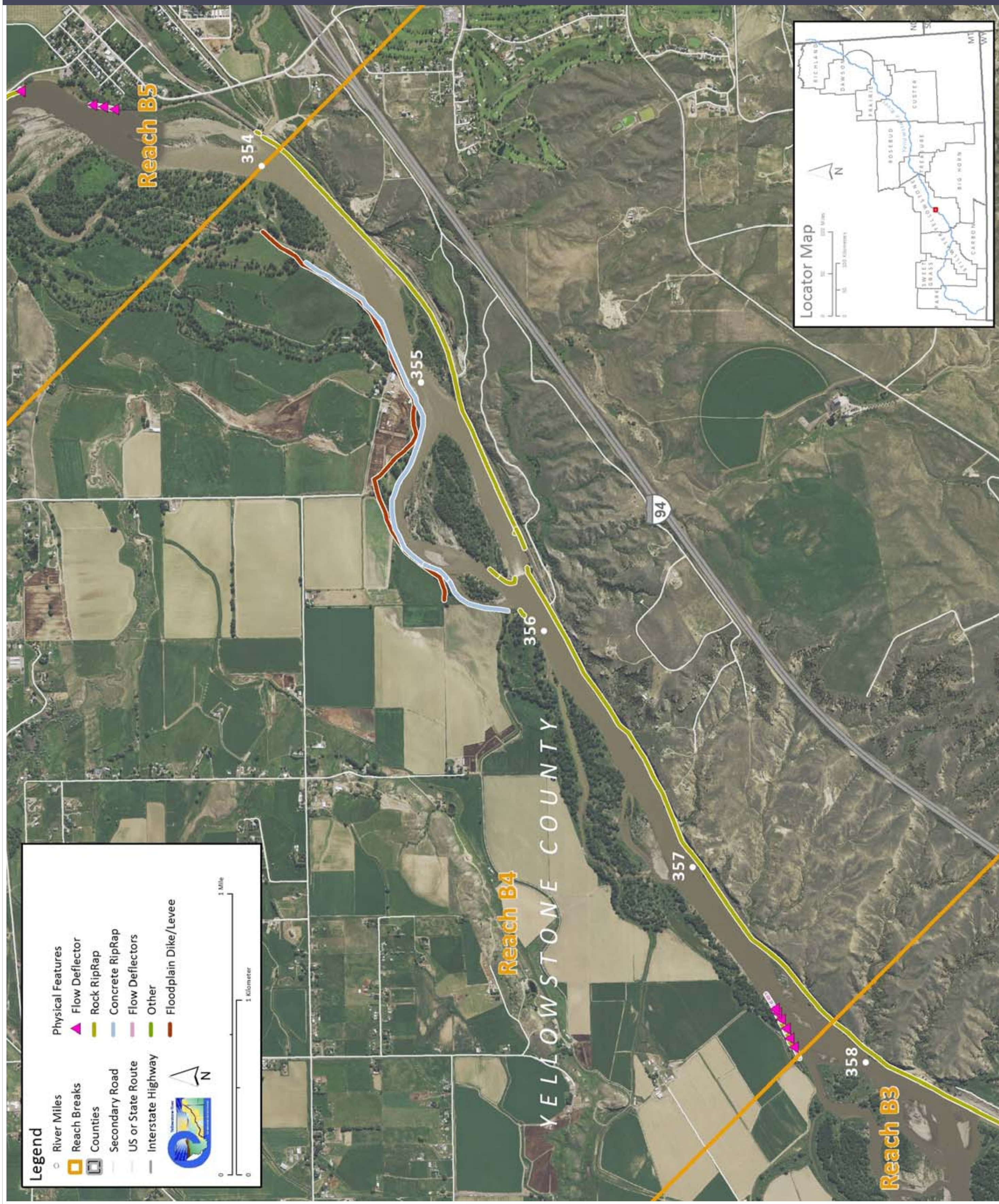
About 2.3 acres of Russian olive have been mapped in Reach B4.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 24,000 cfs to 19,900 cfs, a drop of about 17 percent. The 2-year flood, which strongly influences overall channel form, has dropped from 44,700 cfs to 40,300 cfs, which is a reduction of 10 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,940 cfs to 2,010 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B4 include:
•Flanking of flow deflectors
•Repair of damaged flow deflectors with riprap

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B4 include:
•Flanked flow deflector removal at RM 357.8
•Nutrient management at corrals associated with animal handling facility at RM 355.
•Fish passage at Huntley Diversion Dam
•Watercraft passage at Huntley Diversion Dam
•Irrigation Diversion structure management at Huntley Diversion Dam

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	170.0	6.5

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	24,000	44,700	55,100	61,400	74,300	79,400	91,000	2,940	3,846
Regulated	19,900	40,300	51,000	57,500	71,300	76,800	89,400	2,010	2,227
% Change	-17.08%	-9.84%	-7.44%	-6.35%	-4.04%	-3.27%	-1.76%	-31.63%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	14-May-51	B/W	1:28,400	6214500	13200
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	23-Aug-96	B/W		6214500	4500
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	15-May-04	Color	1:15,840	6214500	5960
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2005	NAIP	07/08/2005	color	1-meter pixels	6214500	11400
2009	NAIP	7/5/2009	Color	1-meter pixels	6214500	23800
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/24/2011	Color	1-meter pixels	6214500	22800
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	19,525	49.1%	20,730	52.1%	1,205
	Flow Deflectors	338	0.8%	258	0.6%	-80
	Concrete RipRap	8,833	22.2%	8,332	20.9%	-502
	Between Flow Deflectors	976	2.5%	0	0.0%	-976
	Feature Type Totals	**29,672**	**74.6%**	**29,319**	**73.7%**	**-353**
Floodplain Control						
	Transportation Encroachment	4,465	11.2%	4,465	11.2%	0
	Floodplain Dike/Levee	8,976	22.6%	8,976	22.6%	0
	Feature Type Totals	**13,441**	**33.8%**	**13,441**	**33.8%**	**0**
	Reach Totals	**43,113**	**108.3%**	**42,760**	**107.5%**	**-353**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	5,550	0	3,280	0	0	0	0	0
Rock RipRap	3,004	0	462	0	0	23,705	0	0
Totals	**8,554**	**0**	**3,742**	**0**	**0**	**23,705**	**0**	**0**

Bankline/Floodplain Inventory: Time Series

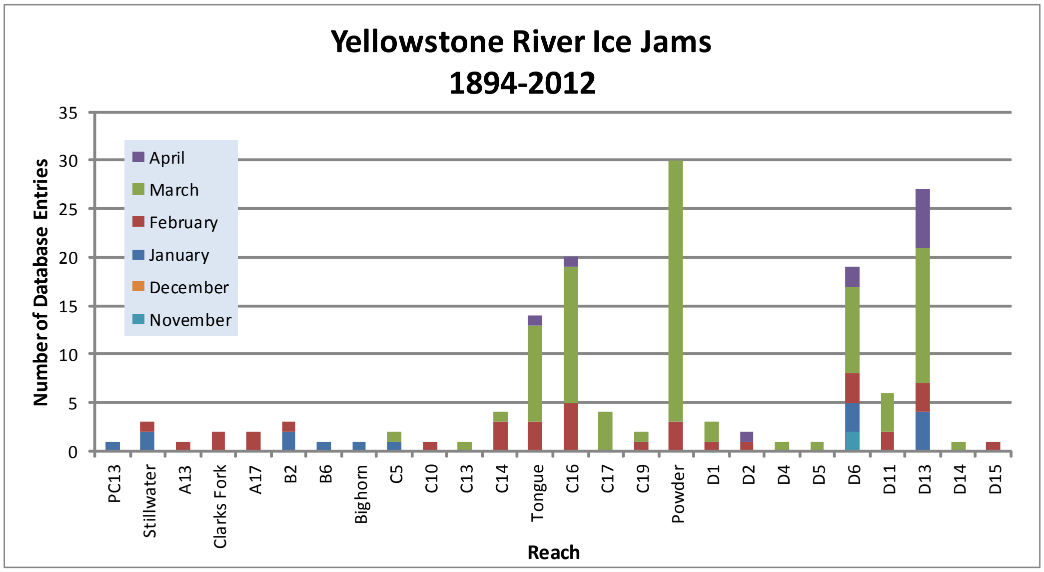
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	In Channel Diversion	237	474	237	237	237	237
	Floodplain Dike/Levee	13,375	13,375	13,375	13,375	13,375	13,375
	Totals	**13,612**	**13,849**	**13,612**	**13,612**	**13,612**	**13,612**
Other Off Channel							
	Floodplain Dike/Levee	0	4,705	4,705	4,705	4,705	4,705
	Floodplain Dike/Levee	0	4,300	4,300	4,300	4,300	4,300
	Totals	**0**	**9,005**	**9,005**	**9,005**	**9,005**	**9,005**
Stream Stabilization							
	Rock RipRap	18,166	18,166	18,166	18,406	18,406	18,406
	Flow Deflector	0	3,241	3,241	3,241	3,241	3,241
	Concrete RipRap	0	6,452	6,452	6,960	6,960	6,960

Totals	**18,166**	**27,859**	**27,859**	**28,607**	**28,607**	**28,607**
Transportation Encroachment						
Railroad	13,543	13,543	13,543	13,543	13,543	13,543
Other	619	619	619	619	619	619
Totals	**14,162**	**14,162**	**14,162**	**14,162**	**14,162**	**14,162**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	19,950	9,303	1.47	1950 to 1976:	-2.55%
1976	20,116	8,627	1.43	1976 to 1995:	-3.42%
1995	20,165	7,663	1.38	1995 to 2001:	14.31%
2001	19,897	11,490	1.58	1950 to 2001:	7.58%
Change 1950 - 2001	**-53**	**2,188**	**0.11**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	29	2.2%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1262		1159	
Total Floodplain Area (Ac)	1291		1290	
Total Isolated (Ac)	**29**	**2.2%**	**132**	**14.1%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	279	0	0	**279**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
332	663	831	236	28%	266	249	93%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Irrigated	26	2.3%
RipRap			
	Railroad	63	5.7%
	Irrigated	396	35.8%
	Totals	**484**	**43.8%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
193.1	0.0	0.0	0.0	10.8

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	6	6	6	6	0.2%	0.2%	0.2%	0.2%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	70	128	157	162	2.1%	3.9%	4.8%	5.0%
	Totals	**76**	**134**	**163**	**168**	**2.3%**	**4.1%**	**5.0%**	**5.1%**
Agricultural Land									
	Non-Irrigated	2,048	1,520	1,338	1,391	62.8%	46.6%	41.0%	42.7%
	Irrigated	728	1,167	1,261	1,161	22.3%	35.8%	38.7%	35.6%
	Totals	**2,775**	**2,686**	**2,599**	**2,552**	**85.1%**	**82.4%**	**79.7%**	**78.3%**
Channel									
	Channel	388	380	423	440	11.9%	11.7%	13.0%	13.5%
	Totals	**388**	**380**	**423**	**440**	**11.9%**	**11.7%**	**13.0%**	**13.5%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	5	0.0%	0.0%	0.0%	0.1%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	17	36	0.0%	0.0%	0.5%	1.1%
	Totals	**0**	**0**	**17**	**41**	**0.0%**	**0.0%**	**0.5%**	**1.3%**
Transportation									
	Public Road	8	8	8	8	0.2%	0.2%	0.2%	0.2%
	Interstate	0	30	30	30	0.0%	0.9%	0.9%	0.9%
	Railroad	14	22	22	22	0.4%	0.7%	0.7%	0.7%
	Totals	**22**	**60**	**59**	**59**	**0.7%**	**1.8%**	**1.8%**	**1.8%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	728	1,167	1,261	1,161	26.2%	43.4%	48.5%	45.5%	17.2%	5.1%	-3.0%	19.3%
	Totals	**728**	**1,167**	**1,261**	**1,161**	**26.2%**	**43.4%**	**48.5%**	**45.5%**	**17.2%**	**5.1%**	**-3.0%**	**19.3%**

Non-Irrigated													
	Multi-Use	1,394	1,284	1,333	1,271	50.2%	47.8%	51.3%	49.8%	-2.4%	3.5%	-1.5%	-0.4%
	Hay/Pasture	654	235	4	120	23.6%	8.8%	0.2%	4.7%	-14.8%	-8.6%	4.5%	-18.9%
	Totals	**2,048**	**1,520**	**1,338**	**1,391**	**73.8%**	**56.6%**	**51.5%**	**54.5%**	**-17.2%**	**-5.1%**	**3.0%**	**-19.3%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	7.6	1.2	1.8	2.5	2.4	1.2	4.0	2.9	1.9
Max	29.2	7.6	34.1	111.8	129.6	136.5	26.2	34.4	40.6
Average	17.1	4.9	14.2	35.4	40.3	23.2	17.8	17.7	13.1
Sum	102.5	24.6	85.3	283.4	282.0	208.4	53.3	53.1	117.6

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	82.4
Channel to Riparian (acres)	68.2
Riparian Encroachment (acres)	**-14.2**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	68.0
1950s Floodplain Mapped as 2011 Channel (Ac)	16.4
Total Recruitment (1950s to 2011)(Ac)	**84.4**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	17.0	34.3	8.1	0.0	**59.5**
Acres/Valley Mile	4.6	9.2	2.2	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	2.29	1.08%	16.12	0.49	0.70	0.08

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
	✓	Bigmouth buffalo
✓	✓	Black bullhead
	✓	Black crappie
		Blue sucker
✓	✓	Bluegill
✓	✓	Brook stickleback
✓	✓	Brown trout
	✓	Burbot
		Catfish species
✓	✓	Channel catfish
✓	✓	Common carp
		Creek chub
✓	✓	Emerald shiner
✓	✓	Fathead minnow
✓	✓	Flathead chub
		Freshwater drum
✓	✓	Goldeye
✓	✓	Green sunfish
	✓	Lake chub
✓	✓	Largemouth bass
✓	✓	Longnose dace
✓	✓	Longnose sucker
	✓	Minnow species
	✓	Mottled sculpin
✓	✓	Mountain sucker
✓	✓	Mountain whitefish
		Northern pike
		Northern plains killifish
		Northern redbelly dace
		Pallid sturgeon
	✓	Pumpkinseed
✓	✓	Rainbow trout
✓	✓	River carpsucker
		Rock bass
✓	✓	Sand shiner
	✓	Sauger
✓	✓	Shorthead redhorse
		Shortnose gar
		Shovelnose sturgeon
		Sicklefin chub
✓	✓	Smallmouth bass
		Smallmouth buffalo
✓	✓	Stonecat
		Sturgeon chub
✓	✓	Sucker species
	✓	Sunfish species
		Walleye
✓	✓	Western silvery minnow
		White bass
	✓	White crappie
✓	✓	White sucker
		Yellow bullhead
✓	✓	Yellow perch

Low Flow Fisheries Habitat Mapping

2001 (Acres)

Habitat	Bankfull	Low Flow	% of Low Flow
Rip Rap Bottom	48.1	23.2	5.5%
Rip Rap Margin	96.3	56.3	13.3%
Secondary Channel	0.7	0.6	0.1%
Secondary Channel (Seasonal)	78.7	53.2	12.6%
Channel Crossover	58.6	28.9	6.8%
Point Bar		11.4	2.7%
Side Bar		23.2	5.5%
Mid-channel Bar		18.0	4.2%
Island	80.9	80.9	19.1%
Dry Channel		77.8	18.4%
Dam Influenced	59.4	49.2	11.6%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

Yellowstone River Reach Narratives — Reach B5

County	Yellowstone	**Upstream River Mile**	354
Classification	UA: Unconfined anabranching	**Downstream River Mile**	346.7
General Location	Huntley: includes Spraklin Island	**Length**	7.30 mi (11.75 km)

General Comments Just downstream of Huntley, Reach B5 provides a good example of floodplain isolation by structures, which is potentially exacerbated by hydrologic alterations.

Narrative Summary

Reach B5 is 7.4 miles long and is located near Huntley and Spraklin Island. The reach is an Unconfined Anabranching (UA) reach type, which indicates little influence by the valley wall coupled with relatively extensive forested islands and side channels. These reach types tend to be the most dynamic within the river corridor. Reach B5 flows northward though a wide valley section where the relatively erodible Bearpaw shale has retreated over geologic time, leaving an unusually broad river corridor. In Reach B5 the river crosses the valley from south to north, further contributing to the lack of confinement and allowance for channel migration.

About 12 percent of the bankline in Reach B5 is armored. In 2011, there was about a mile of concrete riprap, a half mile of rock riprap, and 1,500 feet of flow deflectors in the reach. Over the decade prior to that, however, 1,200 feet of concrete riprap and 1,150 feet of flow deflectors had eroded out, and 2,000 feet of rock riprap built, indicating a tendency for concrete and flow deflectors to fail coupled by an overall shift towards rock riprap bank protection between 2001 and 2011.

One of the most spectacular examples of barb failures on the Yellowstone River is in Reach B5, where about 1,300 feet of barbs on the left bank just downstream of the Huntley Bridge were flanked between 2001 and 2005. The river then migrated about 200 feet behind the barbs and the bank has since been armored with rock riprap. The flanked barbs remain visible in the middle of the river in 2011 imagery. Another barb was flanked on the left bank at RM 350, and is prominently exposed 65 feet off of the bank. In the lowermost end of the reach at RM 347, about 900 feet of concrete armor was flanked on the right bank, and the river is now up to 200 feet behind the armor, migrating rapidly to the east. This area has seen over 800 feet of river migration since 1950.

Prior to 1950, about 11,400 feet of side channels were blocked in the reach by small dikes. These channels are on both sides of the river just downstream of the Huntley Bridge at RM 352.5. Further downstream at RM 348 there are numerous older swales south of the river that are also blocked.

Land uses in the reach are primarily agricultural, with about 1,300 acres of flood irrigated land mapped as of 2011. There are also almost 600 acres of urban/exurban development. The Channel Migration Zone (CMZ) has been developed for multiple land uses; as of 2011, there were 389 acres of flood irrigation, 24 acres of urban/exurban land, and 10 acres of transportation infrastructure within the CMZ. About 14 percent of the total CMZ footprint has become restricted by bank armor and road prisms.

Trash dumps have been mapped on the left stream bank at RM 351.2, and up on the north bluff at RM 347.1. One large animal handling facility was mapped about 800 feet south of the river at RM 347.8.

About 55 acres of Russian olive have been mapped in Reach B5. The reach also hosts over 200 acres of mapped wetland areas, about 170 acres of which are emergent marshes and wet meadows.

Riparian recruitment in the reach has exceeded 500 acres since 1950; about half of that recruitment occurred in areas that were 1950s channel and the other half in areas that were eroded between 1950 and 2001.

Reach B5 was sampled as part of the avian study. The average species richness in this reach was 8.4, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. Two bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were also found, the Plumbeous Vireo and the Ovenbird.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 25,600 cfs to 21,200 cfs, a drop of about 17 percent. The 2-year flood, which strongly influences overall channel form, has dropped from 47,400 cfs to 42,600 cfs, which is a reduction of 10 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,000 cfs to 2,050 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

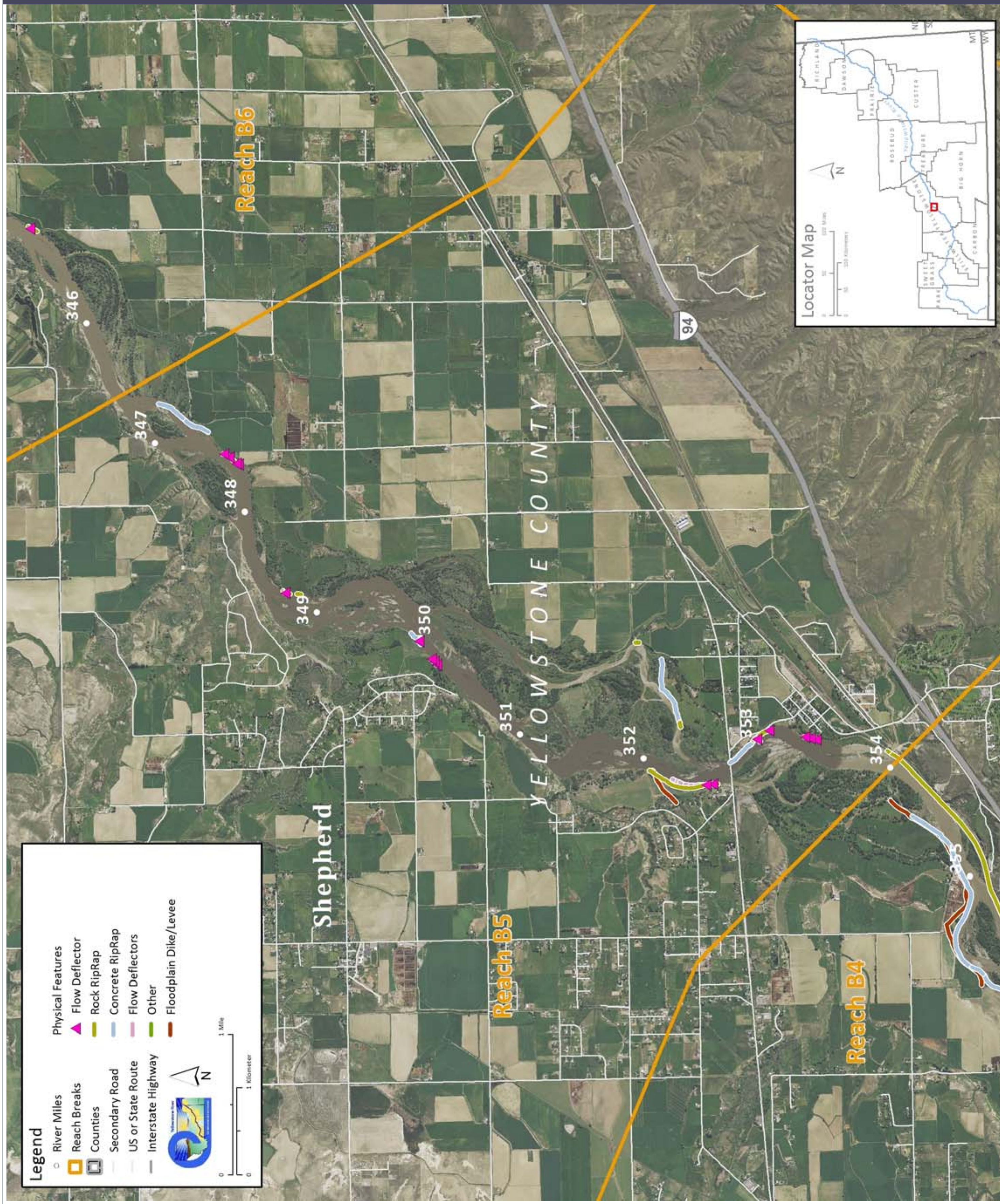
Because of the flow alterations, about 22 percent of the 5-year floodplain has become isolated in Reach B5.

CEA-Related observations in Reach B5 include:
•Flanking of flow deflectors and concrete riprap
•Blockage of over two miles of side channel pre-1950

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B5 include:
•Side channel restoration at RM 352.5
•Flanked flow deflector removal at RM 352.5 and 350.0
•CMZ management due to development within CMZ footprint
•Russian olive removal

•Nutrient management at animal handling facility at RM 347.8.
•Solid waste removal at RM 351.2L and 347.1L

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	162.7	10.4

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	25,600	47,400	58,400	65,100	78,600	84,000	96,100	3,000	3,846
Regulated	21,200	42,600	54,000	61,000	75,400	81,200	94,400	2,050	2,227
% Change	-17.19%	-10.13%	-7.53%	-6.30%	-4.07%	-3.33%	-1.77%	-31.67%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	14-May-51	B/W	1:28,400	6214500	13200
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	8/23/96 - 8/10/96	B/W		6214500	4500
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	15-May-04	Color	1:15,840	6214500	5960
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2009	NAIP	7/5/2009	Color	1-meter pixels	6214500	23800
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/24/2011	Color	1-meter pixels	6214500	22800
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	552	0.7%	2,399	3.1%	1,847
	Flow Deflectors	587	0.7%	736	0.9%	150
	Concrete RipRap	6,579	8.4%	5,361	6.8%	-1,218
	Between Flow Deflectors	2,116	2.7%	813	1.0%	-1,303
	Feature Type Totals	**9,833**	**12.5%**	**9,310**	**11.9%**	**-523**
Floodplain Control						
	Transportation Encroachment	2,694	3.4%	2,694	3.4%	0
	Floodplain Dike/Levee	2,055	2.6%	1,936	2.5%	-119
	Feature Type Totals	**4,749**	**6.1%**	**4,630**	**5.9%**	**-119**
	Reach Totals	**14,582**	**18.6%**	**13,940**	**17.8%**	**-643**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	3,172	1,082	1,099	1,223	0	0	0	0
Flow Deflectors/Between FDs	0	1,617	610	0	0	0	0	476
Rock RipRap	171	0	0	0	0	0	0	0
Totals	**3,342**	**2,699**	**1,709**	**1,223**	**0**	**0**	**0**	**476**

Bankline/Floodplain Inventory: Time Series

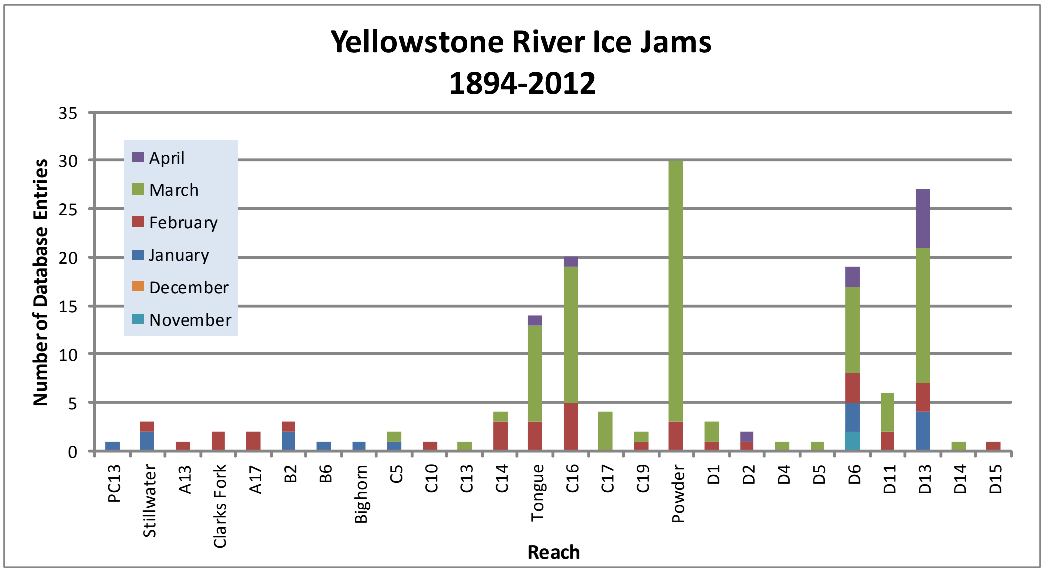
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	1,736	1,736	1,736	1,736	1,736	1,736
	Totals	**1,736**	**1,736**	**1,736**	**1,736**	**1,736**	**1,736**
Other Off Channel							
	Floodplain Dike/Levee	0	2,444	2,444	2,444	2,444	2,444
	Floodplain Dike/Levee	449	449	449	449	449	449
	Totals	**449**	**2,893**	**2,893**	**2,893**	**2,893**	**2,893**
Stream Stabilization							
	Rock RipRap	2,422	2,594	2,594	2,594	2,594	2,594
	Flow Deflector	0	645	645	2,736	1,391	1,391
	Concrete RipRap	2,429	5,218	8,316	9,344	9,344	9,344

Totals	**4,851**	**8,457**	**11,555**	**14,674**	**13,328**	**13,328**
Transportation Encroachment						
Railroad	1,238	1,238	1,238	1,238	1,238	1,238
Other	114	114	209	209	318	318
County Road	2,565	2,565	2,565	2,565	2,565	2,565
Bridge Approach	2,496	2,496	2,496	2,496	2,496	2,496
Totals	**6,412**	**6,412**	**6,507**	**6,507**	**6,617**	**6,617**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	39,051	58,430	2.50
1976	39,578	56,859	2.44
1995	39,826	54,179	2.36
2001	39,214	66,239	2.69
Change 1950 - 2001	**163**	**7,809**	**0.19**

	% Change in Braiding
1950 to 1976:	-2.39%
1976 to 1995:	-3.13%
1995 to 2001:	13.93%
1950 to 2001:	7.73%

Length of Side Channels Blocked

Pre-1950s (ft)	11,393
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	12	0.5%		
Total Not Isolated (Ac)	2320		1956	
Total Floodplain Area (Ac)	2332		2209	
Total Isolated (Ac)	**12**	**0.5%**	**253**	**21.5%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	106	0	0	**106**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
430	860	2,704	322	12%	91	55	60%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	66	2.3%
	Public Road	69	2.4%
RipRap/Flow Deflectors			
	Irrigated	109	3.9%
RipRap			
	Public Road	126	4.5%
	Irrigated	27	0.9%
	Totals	**396**	**14.0%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
305.1	0.0	0.0	50.4	12.5

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	12	12	12	12	0.2%	0.2%	0.2%	0.2%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	81	99	130	147	1.5%	1.8%	2.4%	2.7%
	Totals	**93**	**111**	**142**	**159**	**1.7%**	**2.0%**	**2.6%**	**2.9%**
Agricultural Land									
	Non-Irrigated	2,810	2,108	1,514	1,770	51.5%	38.6%	27.8%	32.5%
	Irrigated	921	1,476	1,644	1,271	16.9%	27.1%	30.2%	23.3%
	Totals	**3,731**	**3,584**	**3,158**	**3,041**	**68.4%**	**65.7%**	**57.9%**	**55.8%**
Channel									
	Channel	1,522	1,428	1,601	1,637	27.9%	26.2%	29.4%	30.0%
	Totals	**1,522**	**1,428**	**1,601**	**1,637**	**27.9%**	**26.2%**	**29.4%**	**30.0%**
ExUrban									
	ExUrban Other	0	7	0	0	0.0%	0.1%	0.0%	0.0%
	ExUrban Undeveloped	20	40	4	4	0.4%	0.7%	0.1%	0.1%
	ExUrban Industrial	0	0	12	12	0.0%	0.0%	0.2%	0.2%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	43	234	488	552	0.8%	4.3%	8.9%	10.1%
	Totals	**63**	**281**	**503**	**567**	**1.2%**	**5.1%**	**9.2%**	**10.4%**
Transportation									
	Public Road	40	39	39	39	0.7%	0.7%	0.7%	0.7%
	Interstate	0	2	2	2	0.0%	0.0%	0.0%	0.0%
	Railroad	5	7	7	7	0.1%	0.1%	0.1%	0.1%
	Totals	**45**	**49**	**49**	**49**	**0.8%**	**0.9%**	**0.9%**	**0.9%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	1	1	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**1**	**1**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	921	1,476	1,644	1,271	24.7%	41.2%	52.1%	41.8%	16.5%	10.9%	-10.3%	17.1%
	Totals	**921**	**1,476**	**1,644**	**1,271**	**24.7%**	**41.2%**	**52.1%**	**41.8%**	**16.5%**	**10.9%**	**-10.3%**	**17.1%**

Non-Irrigated													
	Multi-Use	1,525	1,448	1,192	1,368	40.9%	40.4%	37.7%	45.0%	-0.5%	-2.7%	7.2%	4.1%
	Hay/Pasture	1,286	660	321	402	34.5%	18.4%	10.2%	13.2%	-16.0%	-8.2%	3.0%	-21.2%
	Totals	**2,810**	**2,108**	**1,514**	**1,770**	**75.3%**	**58.8%**	**47.9%**	**58.2%**	**-16.5%**	**-10.9%**	**10.3%**	**-17.1%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.1	0.4	0.1	0.0	0.8	0.6	2.7	1.7	0.2
Max	28.5	67.0	24.9	153.1	171.3	127.2	59.8	31.3	71.5
Average	12.2	10.2	7.3	33.5	31.4	25.1	23.2	17.0	19.1
Sum	268.2	286.5	174.3	636.7	784.5	678.9	370.4	220.5	420.8

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	339.8
Channel to Riparian (acres)	283.6
Riparian Encroachment (acres)	**-56.2**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	285.2
1950s Floodplain Mapped as 2011 Channel (Ac)	239.5
Total Recruitment (1950s to 2011)(Ac)	**524.7**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	17.7	169.8	52.3	0.0	**239.8**
Acres/Valley Mile	2.8	27.1	8.3	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	54.53	3.21%	53.49	5.19	15.73	8.16

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	**Bankfull**	**Low Flow**	**% of Low Flow**
Scour Pool	140.7	68.5	4.2%
Rip Rap Bottom	87.3	46.8	2.9%
Bluff Pool	84.7	60.5	3.7%
Secondary Channel	299.1	117.7	7.2%
Secondary Channel (Seasonal)	252.4	162.3	9.9%
Channel Crossover	150.3	72.0	4.4%
Point Bar		93.1	5.7%
Side Bar		97.2	6.0%
Mid-channel Bar		56.8	3.5%
Island	617.4	617.4	37.8%
Dry Channel		239.5	14.7%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern Potential Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
✓	✓	American Robin		✓	Chipping Sparrow			Killdeer	✓	✓	Song Sparrow
	✓	American Crow		✓	Clay-collared Sparrow			Lark Bunting		✓	Spotted Sandpiper
✓	✓	American Goldfinch			Cliff Swallow	✓	✓	Lark Sparrow	✓	✓	Spotted Towhee
		American Kestrel	✓	✓	Common Grackle	✓	✓	Lazuli Bunting			Sharp-shinned Hawk
✓	✓	American Redstart			Common Merganser	✓	✓	Least Flycatcher		✓	Swainson's Thrush
	✓	Bald Eagle			Common Nighthawk		✓	Mallard			Sandhill Crane
		Baltimore Oriole		✓	Common Raven			Mountain Bluebird	✓	✓	Tree Swallow
	✓	Barn Swallow	✓	✓	Common Yellowthroat	✓	✓	Mourning Dove			Turkey Vulture
	✓	Belted Kingfisher			Cooper's Hawk	✓	✓	Northern Flicker			Upland Sandpiper
	✓	Black-billed Cuckoo		✓	Dickcissel			Orchard Oriole		✓	Vesper Sparrow
	✓	Black-billed Magpie	✓	✓	Downy Woodpecker		✓	Osprey		✓	Violet-green Swallow
✓	✓	Black-capped Chickadee			Eastern Bluebird	✓	✓	Ovenbird	✓	✓	Warbling Vireo
	✓	Black-and-white Warbler	✓	✓	Eastern Kingbird	✓	✓	Plumbeous Vireo		✓	Western Kingbird
✓	✓	Black-headed Grosbeak			Eurasian Collared-dove		✓	Red-headed Woodpecker	✓	✓	Western Meadowlark
	✓	Blue Jay	✓	✓	European Starling			Red-naped Sapsucker	✓	✓	Western Wood-pewee
		Bobolink		✓	Field Sparrow			Red Crossbill	✓	✓	White-breasted Nuthatch
	✓	Brewer's Blackbird			Franklin's Gull		✓	Ring-necked Pheasant		✓	White-throated Swift
✓	✓	Brown-headed Cowbird			Grasshopper Sparrow		✓	Red-tailed hawk			Wild Turkey
		Brown Creeper	✓	✓	Gray Catbird		✓	Rock Dove		✓	Wood Duck
	✓	Brown Thrasher			Great Blue Heron	✓	✓	Red-winged Blackbird			Yellow-bellied Sapsucker
	✓	Bullock's Oriole			Great Horned Owl	✓	✓	Red-eyed Vireo			Yellow-billed Cuckoo
	✓	Canada Goose	✓	✓	Hairy Woodpecker			Red-breasted Grosbeak	✓	✓	Yellow-breasted Chat
✓	✓	Cedar Waxwing		✓	House Finch			Say's Phoebe			Yellow-headed Blackbird
	✓	Chimney Swift	✓	✓	House Wren		✓	Savannah Sparrow	✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Yellowstone	**Upstream River Mile**	346.7
Classification	PCB: Partially confined braided	**Downstream River Mile**	340.6
General Location	Ballantine	**Length**	6.10 mi (9.82 km)
General Comments	Channel closely follows left valley wall		

Narrative Summary

Reach B6 is 6.1 miles long and is located Ballantine. The reach is a Partially Confined Braided (PCB) reach type, which indicates some valley wall influence coupled with relatively extensive unvegetated bars and low flow islands. Within Reach B6, the river flows closely along the north valley wall. The Gritty Stone fishing access site is located in the downstream end of the reach.

About 6.3 percent of the bankline in Reach B6 is armored, and the majority of that armor (2,300 feet) is concrete riprap. Since 2001, riprap has expanded by about 430 feet. Reach B6 also hosts almost 1,500 feet of car body riprap, which is fairly unusual in terms of extent on the Yellowstone River. The car bodies were put in place between 1950 and 1995, and their mapped location is at RM 341.7R, although they are difficult to see on the imagery.

Prior to 1950, a side channel that was about 1,350 feet long was blocked by a small dike at RM 343. Even though this side channel was blocked, there has been a net gain of over three miles of side channel since 1950.

Land uses in the reach are primarily agricultural, with about 1,862 acres of flood irrigated land mapped as of 2011. The Channel Migration Zone (CMZ) has been developed for primarily flood irrigation; as of 2011, there were 237 acres of flood irrigated land in the CMZ, and about 9 percent of the total CMZ footprint has become restricted by bank armor and road prisms. The modern 5-year floodplain contains over 200 acres of flood-irrigated ground.

There is one mapped animal handling facility in the reach at RM 345.5R. It is within 800 feet of the active river bank.

The 100-year floodplain has also been restricted; about 210 acres or 11.4 percent of the historic 100-year floodplain area has become isolated from the river by agricultural infrastructure.

Since 1950, there has been almost 250 acres of riparian recruitment in the reach, and most of that was in the 1950s channels that were abandoned.

One ice jam has been recorded in Reach B6. On January 3, 1997, an ice jam occurred at RM 345 that caused severe flooding and resulted in evacuations.

There are 49 acres of mapped Russian olive in the reach, and the mapping indicates that it has expanded on islands and in side channels. Riparian recruitment in the reach has exceeded 500 acres since 1950; about half of that recruitment occurred in areas that were 1950s channel and the other half in areas that were eroded between 1950 and 2001.

Reach B6 was sampled as part of the avian study. The average species richness in this reach was 8.25, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8.

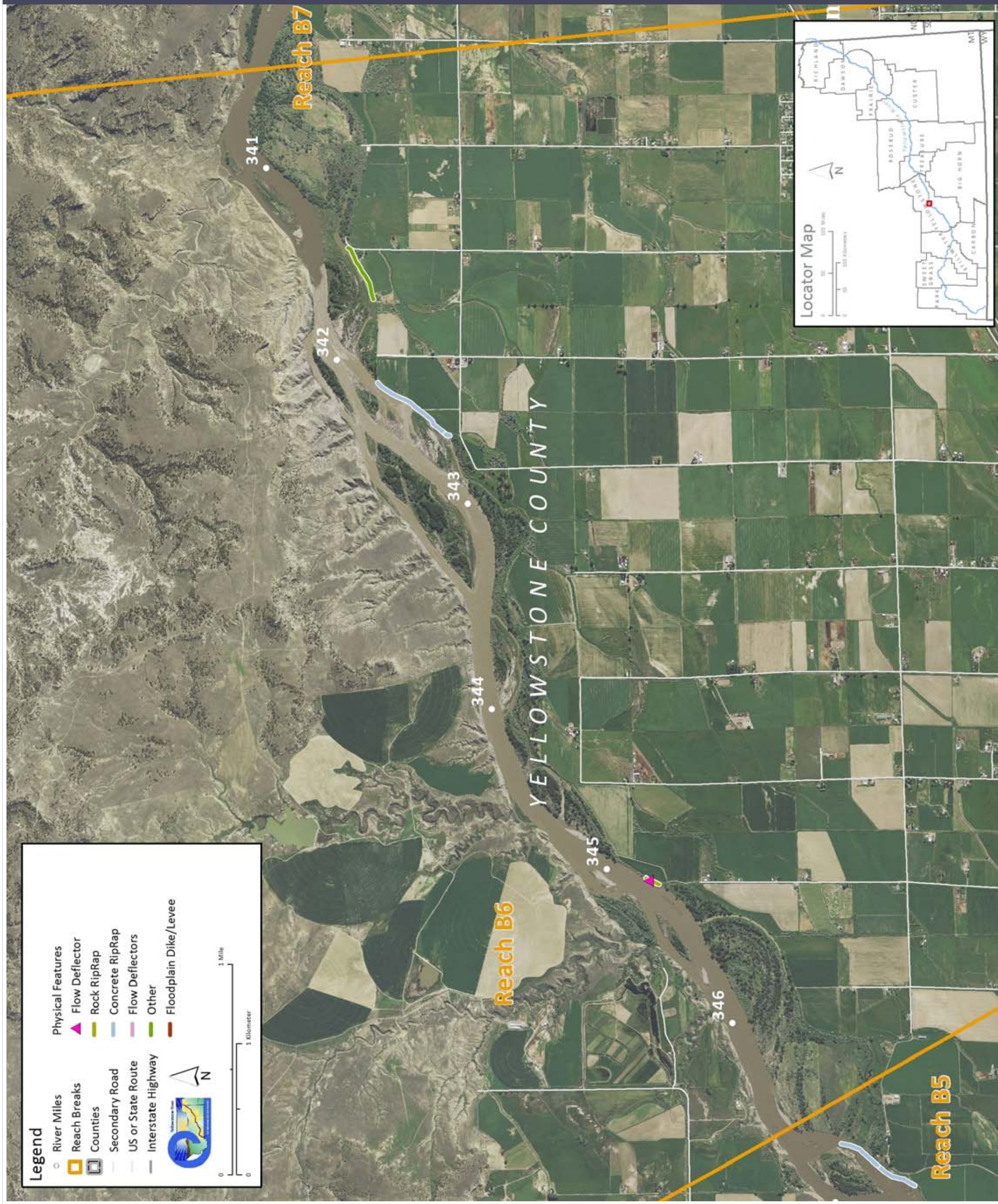
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 26,000 cfs to 21,100 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped from 48,300 cfs to 43,000 cfs, which is a reduction of 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,000 cfs to 2,050 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

Because of the flow alterations, about 25 percent of the 5-year floodplain has become isolated in Reach B6. Much of that 5-year floodplain isolation is within old swales on the south side of the river. The 5-year flood discharge has dropped by 8.25 percent in this reach due to human influences, primarily irrigation.

CEA-Related observations in Reach B6 include:
•Gain in anabranching channel length
•Ice jamming
•Side channel blockage at RM 343.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B6 include:
•Russian olive removal
•Nutrient management at corrals associated with animal handling facility at RM 534.5R

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	156.6	17.7

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	26,000	48,300	59,400	66,200	79,900	85,300	97,700	3,000	3,846
Regulated	21,100	43,000	54,500	61,700	76,300	82,200	95,800	2,050	2,227
% Change	-18.85%	-10.97%	-8.25%	-6.80%	-4.51%	-3.63%	-1.94%	-31.67%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	15-May-51	B/W	1:28,400	6214500	11500
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	8/10/96 - 8/24/96	B/W		6214500	4500
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	15-May-04	Color	1:15,840	6214500	5960
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2005	NAIP	07/12/2005	color	1-meter pixels	6214500	12600
2009	NAIP	7/5/2009	Color	1-meter pixels	6214500	23800
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/24/2011	Color	1-meter pixels	6214500	22800
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	0	0.0%	304	0.5%	304
	Flow Deflectors	0	0.0%	23	0.0%	23
	Concrete RipRap	2,169	3.3%	2,275	3.5%	106
	Car Bodies	1,465	2.3%	1,465	2.3%	0
	Feature Type Totals	**3,634**	**5.6%**	**4,067**	**6.3%**	**433**
	Reach Totals	**3,634**	**5.6%**	**4,067**	**6.3%**	**433**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Car Bodies	984	0	482	0	0	0	0	0
Concrete RipRap	2,168	0	0	0	0	0	0	0
Totals	**3,152**	**0**	**482**	**0**	**0**	**0**	**0**	**0**

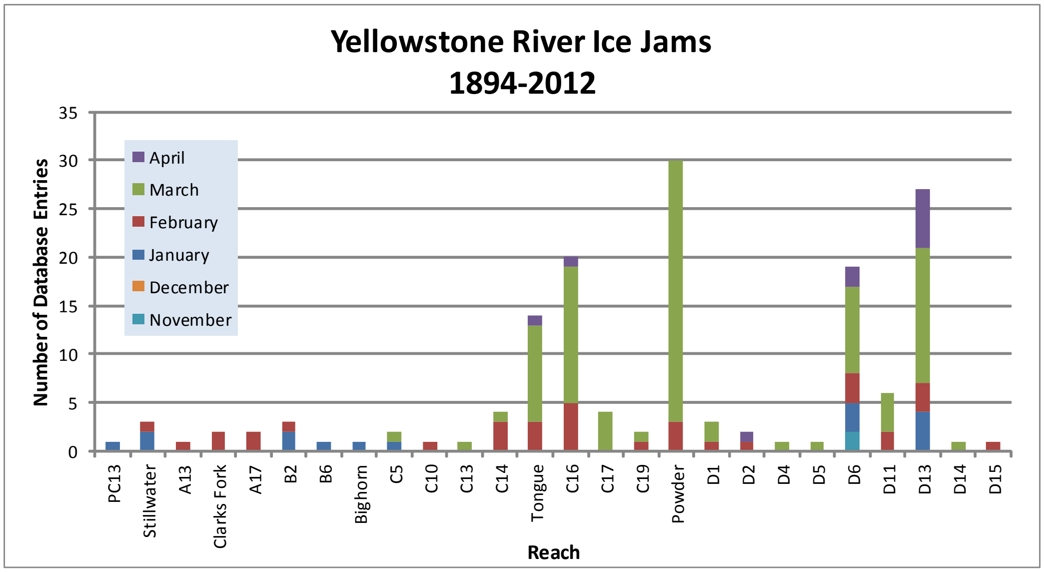
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

Feature Class	Feature Type	Sum of Feature Length (ft) 1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	11,978	12,535	12,865	12,865	12,865	12,865
	Totals	**11,978**	**12,535**	**12,865**	**12,865**	**12,865**	**12,865**
Stream Stabilization							
	Concrete RipRap	0	0	2,981	2,981	2,981	2,981
	Car Bodies	0	1,702	1,702	1,702	1,702	1,702
	Totals	**0**	**1,702**	**4,683**	**4,683**	**4,683**	**4,683**
Transportation Encroachment							
	County Road	3,755	3,755	3,755	3,755	3,755	3,755
	Totals	**3,755**	**3,755**	**3,755**	**3,755**	**3,755**	**3,755**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
1/3/1997	NA	345	Severe flooding, evacuations

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	31,548	26,855	1.85
1976	32,976	36,892	2.12
1995	32,692	32,470	1.99
2001	32,409	43,922	2.36
Change 1950 - 2001	**861**	**17,067**	**0.50**

	% Change in Braiding
1950 to 1976:	14.45%
1976 to 1995:	-5.93%
1995 to 2001:	18.16%
1950 to 2001:	27.22%

Length of Side Channels Blocked

Pre-1950s (ft)	1,352
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	209	11.4%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1621		1659	
Total Floodplain Area (Ac)	1830		2002	
Total Isolated (Ac)	**209**	**11.4%**	**344**	**24.8%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	304	0	0	**304**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
425	850	1,464	128	9%	123	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Irrigated	0	0.0%
RipRap			
	Irrigated	141	8.8%
	Totals	**142**	**8.8%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
236.8	0.0	0.0	0.0	3.6

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	52	65	97	137	1.1%	1.4%	2.1%	3.0%
	Totals	**52**	**65**	**97**	**137**	**1.1%**	**1.4%**	**2.1%**	**3.0%**
Agricultural Land									
	Non-Irrigated	2,365	2,208	1,811	1,737	51.1%	47.7%	39.1%	37.5%
	Irrigated	1,318	1,458	1,946	1,958	28.5%	31.5%	42.0%	42.3%
	Totals	**3,683**	**3,666**	**3,757**	**3,695**	**79.5%**	**79.2%**	**81.1%**	**79.8%**
Channel									
	Channel	879	882	760	778	19.0%	19.1%	16.4%	16.8%
	Totals	**879**	**882**	**760**	**778**	**19.0%**	**19.1%**	**16.4%**	**16.8%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	17	17	17	17	0.4%	0.4%	0.4%	0.4%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**17**	**17**	**17**	**17**	**0.4%**	**0.4%**	**0.4%**	**0.4%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	4	0.0%	0.0%	0.0%	0.1%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**4**	**0.0%**	**0.0%**	**0.0%**	**0.1%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	96	96	0.0%	0.0%	2.6%	2.6%	0.0%	2.6%	0.0%	2.6%
	Flood	1,318	1,458	1,849	1,862	35.8%	39.8%	49.2%	50.4%	4.0%	9.5%	1.2%	14.6%
	Totals	**1,318**	**1,458**	**1,946**	**1,958**	**35.8%**	**39.8%**	**51.8%**	**53.0%**	**4.0%**	**12.0%**	**1.2%**	**17.2%**

Non-Irrigated													
	Multi-Use	1,683	1,584	1,725	1,675	45.7%	43.2%	45.9%	45.3%	-2.5%	2.7%	-0.6%	-0.4%
	Hay/Pasture	682	624	87	61	18.5%	17.0%	2.3%	1.7%	-1.5%	-14.7%	-0.6%	-16.9%
	Totals	**2,365**	**2,208**	**1,811**	**1,737**	**64.2%**	**60.2%**	**48.2%**	**47.0%**	**-4.0%**	**-12.0%**	**-1.2%**	**-17.2%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	1.1	1.0	0.5	1.5	0.9	0.4	1.2	0.7	0.7
Max	81.4	33.0	110.7	96.3	139.5	147.3	28.0	98.0	22.3
Average	10.2	7.0	13.4	34.6	24.9	20.5	10.6	20.1	8.9
Sum	194.0	104.9	255.5	380.5	373.4	349.0	84.5	161.0	53.5

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	179.5
Channel to Riparian (acres)	143.0
Riparian Encroachment (acres)	**-36.5**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	156.8
1950s Floodplain Mapped as 2011 Channel (Ac)	89.2
Total Recruitment (1950s to 2011)(Ac)	**246.0**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	2.9	71.5	38.0	0.0	**112.4**
Acres/Valley Mile	0.5	12.7	6.7	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	48.71	2.83%	15.00	0.55	10.97	11.24

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	214.4	115.9	15.3%
Rip Rap Bottom	5.8	5.5	0.7%
Bluff Pool	82.9	57.4	7.6%
Secondary Channel	69.6	21.4	2.8%
Secondary Channel (Seasonal)	137.6	104.6	13.8%
Channel Crossover	107.5	68.4	9.0%
Point Bar		44.5	5.9%
Side Bar		57.1	7.5%
Mid-channel Bar		40.7	5.4%
Island	141.8	144.3	19.0%
Dry Channel		99.8	13.1%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern

Potential Species of Concern

Reach	Region	
✓	✓	American Robin
	✓	American Crow
✓	✓	American Goldfinch
		American Kestrel
✓	✓	American Redstart
	✓	Bald Eagle
		Baltimore Oriole
	✓	Barn Swallow
	✓	Belted Kingfisher
	✓	Black-billed Cuckoo
	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
	✓	Black-and-white Warbler
	✓	Black-headed Grosbeak
	✓	Blue Jay
		Bobolink
	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
		Brown Creeper
	✓	Brown Thrasher
	✓	Bullock's Oriole
	✓	Canada Goose
✓	✓	Cedar Waxwing
	✓	Chimney Swift
	✓	Chipping Sparrow
	✓	Clay-collared Sparrow
		Cliff Swallow
✓	✓	Common Grackle
		Common Merganser
		Common Nighthawk
	✓	Common Raven
✓	✓	Common Yellowthroat
		Cooper's Hawk
	✓	Dickcissel
	✓	Downy Woodpecker
		Eastern Bluebird
	✓	Eastern Kingbird
		Eurasian Collared-dove
✓	✓	European Starling
✓	✓	Field Sparrow
		Franklin's Gull
		Grasshopper Sparrow
	✓	Gray Catbird
		Great Blue Heron
		Great Horned Owl
	✓	Hairy Woodpecker
	✓	House Finch
✓	✓	House Wren
		Killdeer
		Lark Bunting
	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
	✓	Mallard
		Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
		Orchard Oriole
	✓	Osprey
	✓	Ovenbird
	✓	Plumbeous Vireo
	✓	Red-headed Woodpecker
		Red-naped Sapsucker
		Red Crossbill
	✓	Ring-necked Pheasant
	✓	Red-tailed hawk
	✓	Rock Dove
✓	✓	Red-winged Blackbird
	✓	Red-eyed Vireo
		Red-breasted Grosbeak
		Say's Phoebe
	✓	Savannah Sparrow
✓	✓	Song Sparrow
	✓	Spotted Sandpiper
✓	✓	Spotted Towhee
		Sharp-shinned Hawk
✓	✓	Swainson's Thrush
		Sandhill Crane
✓	✓	Tree Swallow
		Turkey Vulture
		Upland Sandpiper
	✓	Vesper Sparrow
	✓	Violet-green Swallow
✓	✓	Warbling Vireo
	✓	Western Kingbird
	✓	Western Meadowlark
✓	✓	Western Wood-pewee
	✓	White-breasted Nuthatch
	✓	White-throated Swift
		Wild Turkey
	✓	Wood Duck
		Yellow-bellied Sapsucker
		Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
		Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Yellowstone	**Upstream River Mile**	340.6
Classification	UB: Unconfined braided	**Downstream River Mile**	331.8
General Location	To Pompey's Pillar	**Length**	8.80 mi (14.16 km)
General Comments	Unconfined reach		

Narrative Summary

Reach B7 is located just upstream of Pompey's Pillar. The Reach is almost nine miles long and is currently largely unconfined with a primary channel thread and numerous mid-channel bars and point bars. In the 1950's, the main channel flowed more closely along the north valley wall; southward migration since that time has reduced the influence of the valley wall on stream geomorphology. The valley is wide in this area, which is typical where the bounding rock units are made up of the relatively erodible Cretaceous-age Bearpaw shale.

Only 290 feet of the streambank in Reach B7 is armored, and no side channels have been blocked.

Land uses in the reach are primarily agricultural, with about 1,340 acres of flood irrigated land mapped as of 2011. The Channel Migration Zone (CMZ) has been developed for primarily flood irrigation; as of 2011, there were 390 acres of flood irrigated land in the CMZ, and about 4 percent of the total CMZ footprint has become restricted by bank armor and road prisms. The modern 5-year floodplain contains over 275 acres of flood-irrigated ground.

Reach B7 shows major southward migration of the river since 1950, with one area experiencing over 1,600 feet of migration over the past 60 years. The river has gained length, and the valley wall influence has become much less prevalent, as virtually all migration in this and adjacent reaches has been to the south. Since 1950 this section of river has lost almost 20,000 feet of anabranching channel length, and there is no strong indication that this loss is directly associated with floodplain dikes. Rather, it appears that significant lengths of anabranching channels were passively abandoned, which may be the consequence of a 19 percent reduction in the mean annual flood due to human influences.

South of the river over 600 acres of historic 100-year floodplain have been isolated from the river by the railroad. This includes a very broad area between the railroad and Interstate that will likely remain isolated since it is over 3,000 feet from the modern river. This area represents 22 percent of the total historic 100-year floodplain area.

The mouth of Arrow Creek is in Reach B7, and the lower portion of the creek has been captured by the river, shortening the tributary and likely driving downcutting upstream.

Reach B7 has 56 mapped acres of Russian olive that can be found in dense stands, however the extensive lateral migration of the river has promoted extensive recruitment of new woody riparian habitat. Since the 1950s there has been about 640 acres of riparian recruitment in the reach. The acreage of recruitment has exceeded that of erosion of riparian areas by 131 acres. Additionally, there are 260 mapped wetlands in the reach, including 135 acres of wet meadows and marsh.

Reach B7 was sampled as part of the avian study. The average species richness in this reach was 8.8, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. One bird species identified by the Montana Natural Heritage Program as a Potential Species of Concern (PSOC) was identified, the Dickscissel. Another species identified as a Species of Concern (SOC) was identified, the Red-headed Woodpecker.

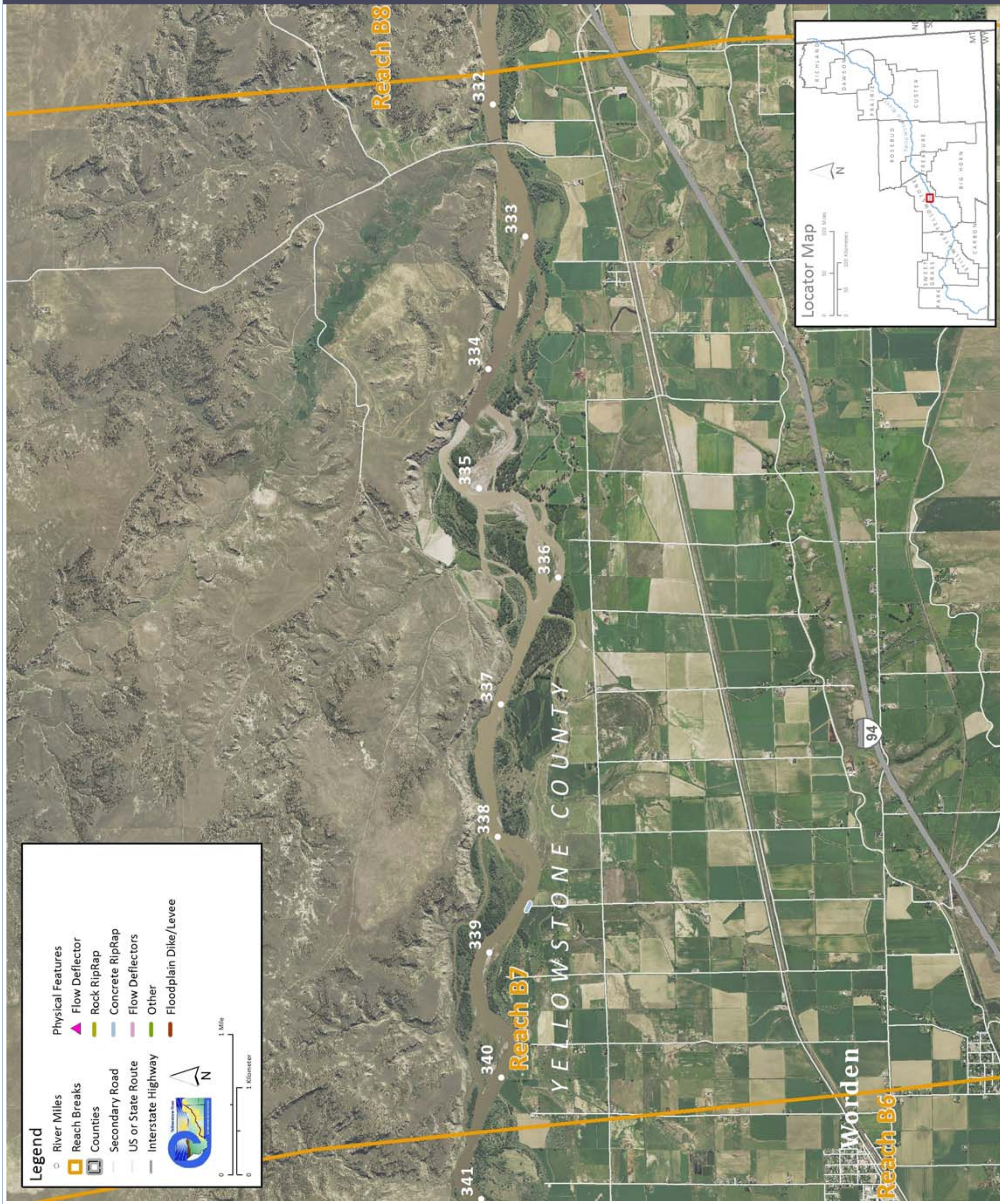
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 27,200 cfs to 22,100 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,010 cfs to 2,060 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

Because of the flow alterations, about 28 percent of the 5-year floodplain has become isolated in Reach B7. Much of that 5-year floodplain isolation is within irrigated fields on the south side of the river.

CEA-Related observations in Reach B7 include:
•Migration away from valley wall resulting in loss of bluff pool habitat.
•Passive abandonment of anabranching channels likely associated with reduced mean annual flows.
•Rapid channel migration through cleared, often flood irrigated fields.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B7 include:
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	147.8	23.8

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	27,200	50,400	62,000	69,000	83,100	88,800	102,000	3,010	3,846
Regulated	22,100	44,900	56,900	64,300	79,400	85,600	100,000	2,060	2,227
% Change	-18.75%	-10.91%	-8.23%	-6.81%	-4.45%	-3.60%	-1.96%	-31.56%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	NARA	July 9-27, 1950	B/W		6214500	29500
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	24-Aug-96	B/W		6214500	4350
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	15-May-04	Color	1:15,840	6214500	5960
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2005	NAIP	07/12/2005	color	1-meter pixels	6214500	12600
2005	NAIP	07/09/2005	color	1-meter pixels	6214500	11100
2009	NAIP	7/5/2009	Color	1-meter pixels	6214500	23800
2009	NAIP	6/29/2009	Color	1-meter pixels	6214500	26200
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/24/2011	Color	1-meter pixels	6214500	22800
2011	NAIP	7/16/2011	Color	1-meter pixels	6214500	36000
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Concrete RipRap	289	0.3%	289	0.3%	0
	Feature Type Totals	**289**	**0.3%**	**289**	**0.3%**	**0**
	Reach Totals	**289**	**0.3%**	**289**	**0.3%**	**0**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	0	0	289	0	0	0	0	0
Totals	**0**	**0**	**289**	**0**	**0**	**0**	**0**	**0**

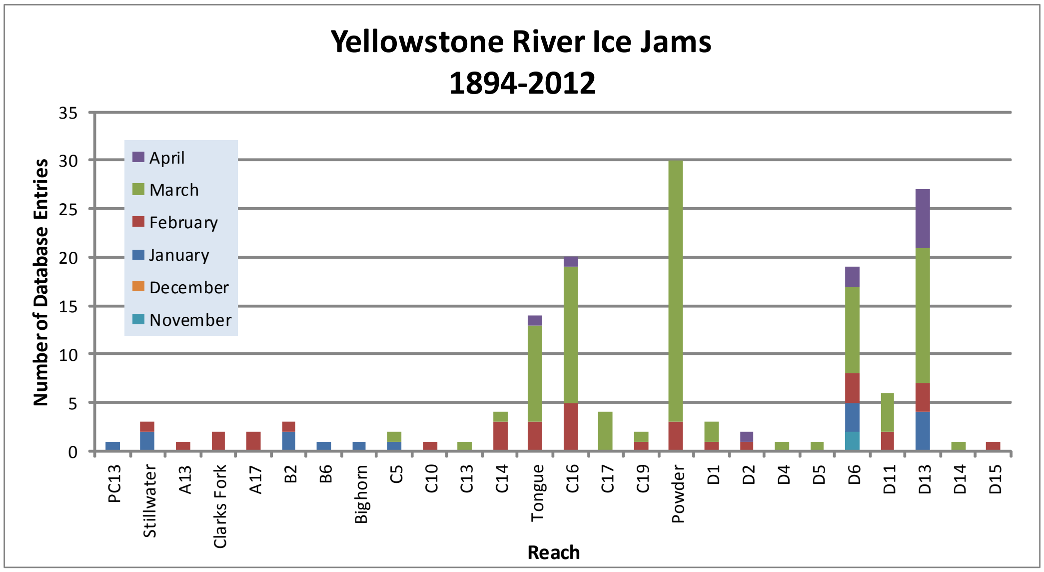
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	7,487	7,487	7,487	7,487	7,487	7,487
	Totals	**7,487**	**7,487**	**7,487**	**7,487**	**7,487**	**7,487**
Other Off Channel							
	Floodplain Dike/Levee	1,296	2,794	2,794	2,794	2,794	2,794
	Totals	**1,296**	**2,794**	**2,794**	**2,794**	**2,794**	**2,794**
Stream Stabilization							
	Rock RipRap	240	240	511	692	692	692
	Concrete RipRap	0	0	428	1,147	1,619	1,619
	Totals	**240**	**240**	**939**	**1,839**	**2,311**	**2,311**
Transportation Encroachment							
	Other	685	685	685	685	685	685
	County Road	2,068	2,068	2,068	2,068	2,068	2,068
	Bridge Approach	2,731	2,731	2,731	4,064	4,064	4,064
	Totals	**5,485**	**5,485**	**5,485**	**6,818**	**6,818**	**6,818**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	44,372	71,314	2.61	1950 to 1976:	-1.11%
1976	42,962	67,805	2.58	1976 to 1995:	-25.15%
1995	45,882	42,659	1.93	1995 to 2001:	11.34%
2001	45,770	52,567	2.15	1950 to 2001:	-17.59%
Change 1950 - 2001	**1,398**	**-18,747**	**-0.46**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	95	3.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	604	18.9%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	2492		2497	
Total Floodplain Area (Ac)	3191		3108	
Total Isolated (Ac)	**699**	**21.9%**	**611**	**27.9%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	278	0	0	**278**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
665	1,330	2,965	125	4%	4	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	105	3.5%
RipRap			
	Irrigated	20	0.7%
	Totals	**125**	**4.2%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
389.1	0.0	0.0	23.5	9.5

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	61	139	170	188	0.9%	2.2%	2.6%	2.9%
	Totals	**61**	**139**	**170**	**188**	**0.9%**	**2.2%**	**2.6%**	**2.9%**
Agricultural Land									
	Non-Irrigated	3,434	3,221	3,341	3,052	53.3%	50.0%	51.9%	47.4%
	Irrigated	1,212	1,656	1,604	1,339	18.8%	25.7%	24.9%	20.8%
	Totals	**4,647**	**4,876**	**4,946**	**4,392**	**72.1%**	**75.7%**	**76.8%**	**68.2%**
Channel									
	Channel	1,681	1,371	1,256	1,742	26.1%	21.3%	19.5%	27.1%
	Totals	**1,681**	**1,371**	**1,256**	**1,742**	**26.1%**	**21.3%**	**19.5%**	**27.1%**
ExUrban									
	ExUrban Other	0	0	14	23	0.0%	0.0%	0.2%	0.4%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	35	0.0%	0.0%	0.0%	0.5%
	Totals	**0**	**0**	**14**	**58**	**0.0%**	**0.0%**	**0.2%**	**0.9%**
Transportation									
	Public Road	45	45	46	51	0.7%	0.7%	0.7%	0.8%
	Interstate	0	1	1	1	0.0%	0.0%	0.0%	0.0%
	Railroad	9	9	9	9	0.1%	0.1%	0.1%	0.1%
	Totals	**54**	**54**	**55**	**61**	**0.8%**	**0.8%**	**0.9%**	**0.9%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	1,212	1,656	1,604	1,339	26.1%	34.0%	32.4%	30.5%	7.9%	-1.5%	-1.9%	4.4%
	Totals	**1,212**	**1,656**	**1,604**	**1,339**	**26.1%**	**34.0%**	**32.4%**	**30.5%**	**7.9%**	**-1.5%**	**-1.9%**	**4.4%**

Non-Irrigated												
Multi-Use	2,874	2,580	2,845	2,492	61.9%	52.9%	57.5%	56.7%	-8.9%	4.6%	-0.8%	-5.1%
Hay/Pasture	560	640	497	561	12.0%	13.1%	10.0%	12.8%	1.1%	-3.1%	2.7%	0.7%
Totals	**3,434**	**3,221**	**3,341**	**3,052**	**73.9%**	**66.0%**	**67.6%**	**69.5%**	**-7.9%**	**1.5%**	**1.9%**	**-4.4%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.3	0.3	0.6	0.5	0.8	1.1	1.2	0.4	0.8
Max	41.4	31.7	138.4	100.5	65.7	50.9	80.8	107.7	57.6
Average	6.7	7.3	14.1	16.6	17.5	14.5	14.3	14.0	16.1
Sum	308.9	301.0	535.6	430.9	333.4	420.4	272.3	419.0	160.9

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	277.6
Channel to Riparian (acres)	408.4
Riparian Encroachment (acres)	**130.8**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	414.1
1950s Floodplain Mapped as 2011 Channel (Ac)	222.4
Total Recruitment (1950s to 2011)(Ac)	**636.5**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	11.1	135.1	110.7	0.0	**256.9**
Acres/Valley Mile	1.5	17.8	14.6	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	55.68	2.17%	20.65	0.31	26.47	9.33

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	362.1	182.9	14.6%
Rip Rap Bottom	54.7	20.9	1.7%
Bluff Pool	24.3	21.6	1.7%
Secondary Channel		16.8	1.3%
Secondary Channel (Seasonal)	223.8	163.8	13.0%
Channel Crossover	246.9	112.9	9.0%
Point Bar		152.4	12.1%
Side Bar		87.3	7.0%
Mid-channel Bar		40.2	3.2%
Island	344.0	344.0	27.4%
Dry Channel		113.0	9.0%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern Potential Species of Concern

Reach	Region	Species	Reach	Region	Species	Reach	Region	Species	Reach	Region	Species
✓	✓	American Robin	✓	✓	Chipping Sparrow			Killdeer	✓	✓	Song Sparrow
✓	✓	American Crow	✓	✓	Clay-collared Sparrow			Lark Bunting		✓	Spotted Sandpiper
✓	✓	American Goldfinch			Cliff Swallow		✓	Lark Sparrow	✓	✓	Spotted Towhee
		American Kestrel		✓	Common Grackle	✓	✓	Lazuli Bunting			Sharp-shinned Hawk
✓	✓	American Redstart			Common Merganser	✓	✓	Least Flycatcher		✓	Swainson's Thrush
	✓	Bald Eagle			Common Nighthawk		✓	Mallard			Sandhill Crane
✓	✓	Baltimore Oriole		✓	Common Raven			Mountain Bluebird	✓	✓	Tree Swallow
	✓	Barn Swallow	✓	✓	Common Yellowthroat	✓	✓	Mourning Dove			Turkey Vulture
✓	✓	Belted Kingfisher			Cooper's Hawk	✓	✓	Northern Flicker			Upland Sandpiper
	✓	Black-billed Cuckoo	✓	✓	Dickcissel			Orchard Oriole		✓	Vesper Sparrow
✓	✓	Black-billed Magpie	✓	✓	Downy Woodpecker		✓	Osprey	✓	✓	Violet-green Swallow
✓	✓	Black-capped Chickadee			Eastern Bluebird		✓	Ovenbird		✓	Warbling Vireo
	✓	Black-and-white Warbler	✓	✓	Eastern Kingbird		✓	Plumbeous Vireo	✓	✓	Western Kingbird
✓	✓	Black-headed Grosbeak			Eurasian Collared-dove	✓	✓	Red-headed Woodpecker	✓	✓	Western Meadowlark
	✓	Blue Jay	✓	✓	European Starling			Red-naped Sapsucker	✓	✓	Western Wood-pewee
		Bobolink		✓	Field Sparrow			Red Crossbill		✓	White-breasted Nuthatch
	✓	Brewer's Blackbird			Franklin's Gull		✓	Ring-necked Pheasant		✓	White-throated Swift
✓	✓	Brown-headed Cowbird			Grasshopper Sparrow		✓	Red-tailed hawk			Wild Turkey
		Brown Creeper	✓	✓	Gray Catbird		✓	Rock Dove	✓	✓	Wood Duck
	✓	Brown Thrasher			Great Blue Heron		✓	Red-winged Blackbird			Yellow-bellied Sapsucker
✓	✓	Bullock's Oriole			Great Horned Owl	✓	✓	Red-eyed Vireo			Yellow-billed Cuckoo
	✓	Canada Goose	✓	✓	Hairy Woodpecker			Red-breasted Grosbeak	✓	✓	Yellow-breasted Chat
✓	✓	Cedar Waxwing		✓	House Finch			Say's Phoebe			Yellow-headed Blackbird
	✓	Chimney Swift	✓	✓	House Wren		✓	Savannah Sparrow	✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Yellowstone	**Upstream River Mile**	331.8
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	322.7
General Location	Bull Mountain	**Length**	9.10 mi (14.65 km)
General Comments	Pompey's Pillar		

Narrative Summary

Reach B8 is located downstream of Pompey's Pillar. The Reach is 9.1 miles long and is partially confined by the valley wall with numerous forested islands. In the 1950's, the main channel flowed more closely along the north valley wall; southward migration since that time has reduced the influence of the valley wall on stream geomorphology. The valley is wide in this area, which is typical where the bounding rock units are made up of the relatively erodible Cretaceous-age Bearpaw shale.

Just over 3,000 feet of streambank are armored by rock riprap, which is about 3.3 percent of the total bankline. All of the bank armor in the reach is protecting the rail line on the south side of the river. High resolution imagery from fall 2011 indicates that at RM 328 about 570 feet of rock riprap has been flanked on the right bank against the rail line, and that the flanked rock is about 80 feet into the river off of the south bank. Currently, the river is within 100 feet of the rail line and migrating rapidly in that direction.

One side channel that is about 6,200 feet long at RM 326R was blocked prior to 1950.

Land uses in the reach are primarily agricultural, with about 1,240 acres of flood irrigated land mapped as of 2011. There are 124 acres of land in sprinkler and 86 under pivot. The modern 5-year floodplain contains about 250 acres of flood-irrigated ground.

One dump site was mapped on an old swale adjacent to a flood irrigated field at RM 326.5R.

The Channel Migration Zone (CMZ) has been developed for primarily flood irrigation; as of 2011, there were 457 acres of flood irrigated land in the CMZ, and about 7 percent of the total CMZ footprint has become restricted by bank armor and road prisms. The railroad has isolated almost 9 percent of the historic 100-year floodplain in the reach. About 22 percent of the 5-year floodplain has become isolated in Reach B8. Much of that 5-year floodplain isolation is due to transportation infrastructure on the south side of the river.

Similar to Reach B7 upstream, Reach B8 shows major southward migration of the river since 1950, with one area at RM 324.3 experiencing over 1,500 feet of migration over the past 60 years. This southward migration has threatened the rail line at RM 328R.

Overall, the migration rates and floodplain turnover rates have dropped since 1976 from 1.9 acres/valley mile/year from 1950 to 1976 to 1.5 acres/valley mile/year from 1976-2001.

Reach B8 has 91 mapped acres of Russian olive that can be found in dense stands, especially on forested islands. Even so, the extensive lateral migration of the river has promoted extensive recruitment of new woody riparian habitat. Since the 1950s there has been about 600 acres of riparian recruitment in the reach, most of which was riparian colonization of old 1950's channel area. The acreage of recruitment has exceeded that of erosion of riparian areas by 51 acres. Additionally, there are 271 mapped wetlands in the reach, including 147 acres of wet meadows and marsh. The reach contains about 33 wetland acres per valley mile, which is a relatively high value for the Yellowstone River.

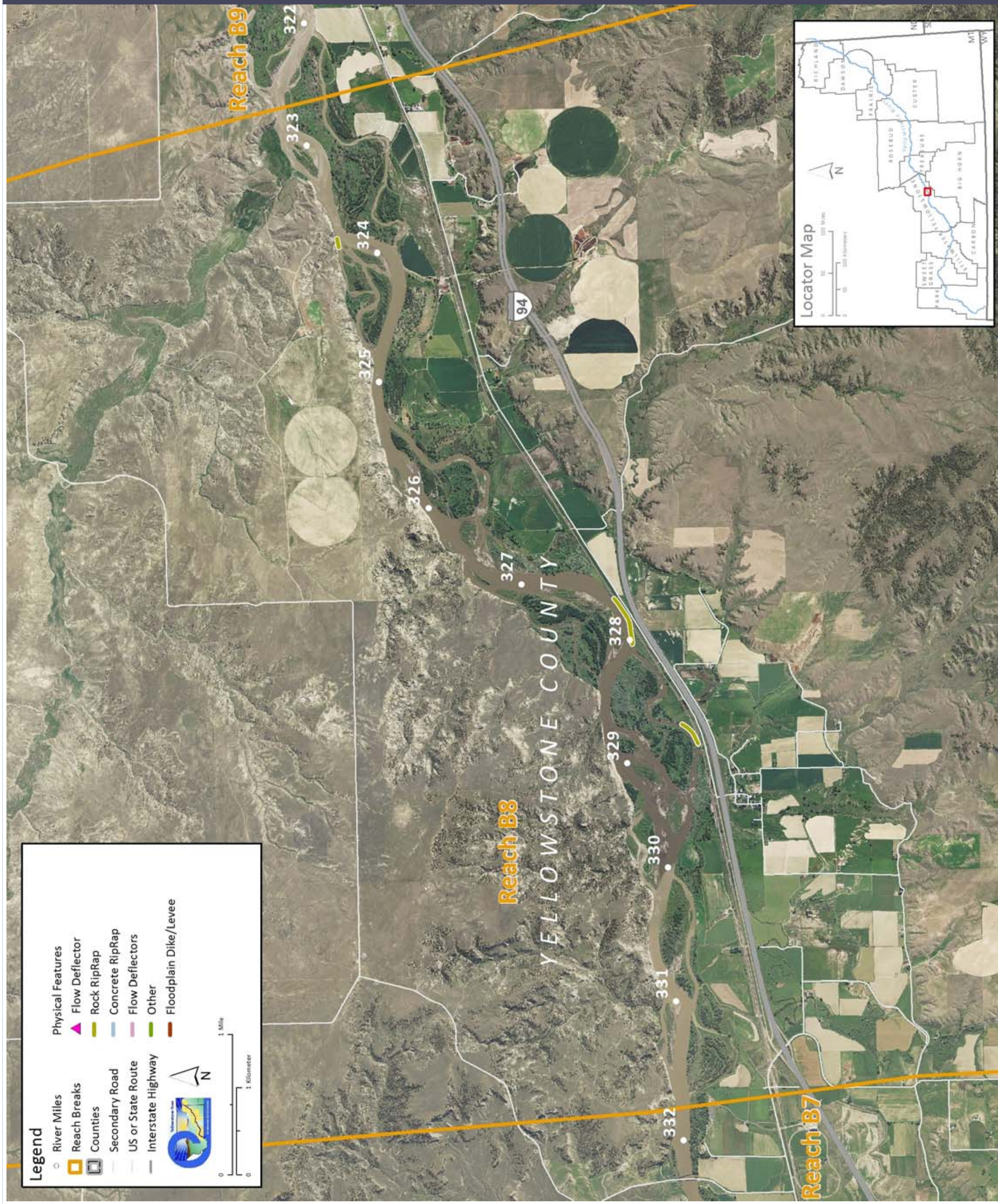
Reach B8 was sampled as part of the avian study. The average species richness in this reach was 7.8, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. One bird species identified by the Montana Natural Heritage Program as a Potential Species of Concern was identified, the Plumbeous Vireo. Another species identified as a Species of Concern was identified, the Red-headed Woodpecker.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 28,000 cfs to 22,800 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,040 cfs to 2,070 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B8 include:
•Migration away from valley wall resulting in loss of bluff pool habitat.
•Blockage of one side channel at RM 326 sometime prior to 1950
•Transportation infrastructure –caused isolation of 5-year floodplain south of the river at RM 329.5

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B8 include:
•Side channel reactivation at RM 326
•Dump removal at RM 326.5R
•Flanked armor removal at RM 328R
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	138.7	32.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	28,000	51,700	63,500	70,700	85,100	90,900	104,000	3,040	3,846
Regulated	22,800	46,100	58,300	65,800	81,300	87,600	102,000	2,070	2,227
% Change	-18.57%	-10.83%	-8.19%	-6.93%	-4.47%	-3.63%	-1.92%	-31.91%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	NARA	July 9-27, 1950	B/W		6214500	29500
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	7/29/96 - 9/11/96	B/W		6214500	10400
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	5/15/04 - 5/14/04	Color	1:15,840	6214500	5960
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2005	NAIP	07/09/2005	color	1-meter pixels	6214500	11100
2009	NAIP	6/29/2009	Color	1-meter pixels	6214500	26200
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/16/2011	Color	1-meter pixels	6214500	36000
2013	NAIP	06/16/2013	color	1-meter pixels	6214500	
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	3,209	3.3%	3,209	3.3%	0
	Feature Type Totals	**3,209**	**3.3%**	**3,209**	**3.3%**	**0**
Floodplain Control						
	Transportation Encroachment	13,957	14.5%	13,957	14.5%	0
	Feature Type Totals	**13,957**	**14.5%**	**13,957**	**14.5%**	**0**
	Reach Totals	**17,166**	**17.8%**	**17,166**	**17.8%**	**0**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type		Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap		325	338	0	0	0	1,889	0	0
	Totals	**325**	**338**	**0**	**0**	**0**	**1,889**	**0**	**0**

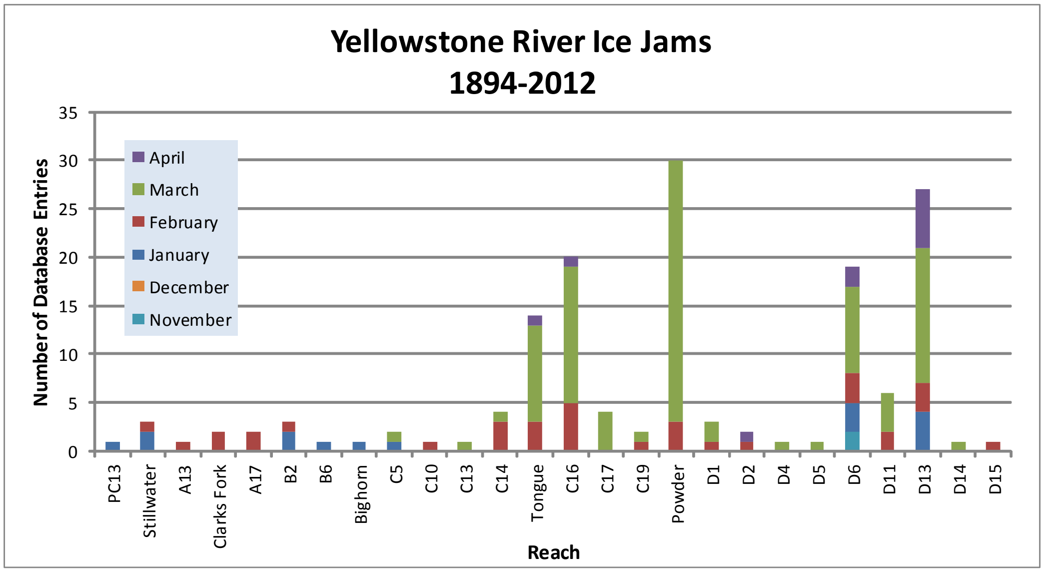
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	0	1,314	1,314	1,314	1,314	1,314
	Totals	**0**	**1,314**	**1,314**	**1,314**	**1,314**	**1,314**
Other Off Channel							
	Floodplain Dike/Levee	0	0	2,190	2,190	2,190	2,190
	Totals	**0**	**0**	**2,190**	**2,190**	**2,190**	**2,190**
Stream Stabilization							
	Rock RipRap	1,010	1,489	2,839	2,839	2,839	2,839
	Flow Deflector	0	0	199	199	199	199
	Totals	**1,010**	**1,489**	**3,038**	**3,038**	**3,038**	**3,038**
Transportation Encroachment							
	Railroad	17,269	17,269	17,269	17,269	17,269	17,269
	Interstate	0	11,402	11,402	11,402	11,402	11,402
	Totals	**17,269**	**28,670**	**28,670**	**28,670**	**28,670**	**28,670**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	51,355	76,381	2.49	1950 to 1976:	-1.05%
1976	46,802	68,389	2.46	1976 to 1995:	11.40%
1995	47,129	82,091	2.74	1995 to 2001:	-7.86%
2001	48,159	73,512	2.53	1950 to 2001:	1.57%
Change 1950 - 2001	**-3,196**	**-2,869**	**0.04**		

Length of Side Channels Blocked

Pre-1950s (ft)	6,209
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	219	8.7%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	2310		2696	
Total Floodplain Area (Ac)	2530		3138	
Total Isolated (Ac)	**219**	**8.7%**	**442**	**21.6%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	251	0	0	**251**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
515	1,031	3,175	224	7%	63	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Railroad	224	6.9%
	Totals	**224**	**6.9%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
456.7	2.7	0.0	3.8	79.8

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	91	105	126	123	1.3%	1.5%	1.8%	1.8%
	Totals	**91**	**105**	**126**	**123**	**1.3%**	**1.5%**	**1.8%**	**1.8%**
Agricultural Land									
	Non-Irrigated	3,613	3,313	3,245	3,057	52.2%	47.9%	46.9%	44.2%
	Irrigated	1,276	1,349	1,386	1,449	18.4%	19.5%	20.0%	20.9%
	Totals	**4,889**	**4,663**	**4,632**	**4,506**	**70.6%**	**67.4%**	**66.9%**	**65.1%**
Channel									
	Channel	1,793	1,853	1,863	1,979	25.9%	26.8%	26.9%	28.6%
	Totals	**1,793**	**1,853**	**1,863**	**1,979**	**25.9%**	**26.8%**	**26.9%**	**28.6%**
ExUrban									
	ExUrban Other	0	0	0	2	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	43	64	64	75	0.6%	0.9%	0.9%	1.1%
	Totals	**43**	**64**	**64**	**77**	**0.6%**	**0.9%**	**0.9%**	**1.1%**
Transportation									
	Public Road	58	63	63	63	0.8%	0.9%	0.9%	0.9%
	Interstate	0	126	126	126	0.0%	1.8%	1.8%	1.8%
	Railroad	47	47	46	46	0.7%	0.7%	0.7%	0.7%
	Totals	**105**	**236**	**235**	**235**	**1.5%**	**3.4%**	**3.4%**	**3.4%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	6	64	124	124	0.1%	1.4%	2.7%	2.8%	1.2%	1.3%	0.1%	2.6%
	Pivot	0	86	86	86	0.0%	1.8%	1.9%	1.9%	1.8%	0.0%	0.1%	1.9%
	Flood	1,270	1,200	1,176	1,239	26.0%	25.7%	25.4%	27.5%	-0.2%	-0.3%	2.1%	1.5%
	Totals	**1,276**	**1,349**	**1,386**	**1,449**	**26.1%**	**28.9%**	**29.9%**	**32.2%**	**2.8%**	**1.0%**	**2.2%**	**6.1%**

Non-Irrigated													
	Multi-Use	3,149	2,837	2,824	2,691	64.4%	60.8%	61.0%	59.7%	-3.6%	0.1%	-1.2%	-4.7%
	Hay/Pasture	464	476	422	366	9.5%	10.2%	9.1%	8.1%	0.7%	-1.1%	-1.0%	-1.4%
	Totals	**3,613**	**3,313**	**3,245**	**3,057**	**73.9%**	**71.1%**	**70.1%**	**67.8%**	**-2.8%**	**-1.0%**	**-2.2%**	**-6.1%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.3	0.5	0.9	0.6	0.8	0.7	1.4	1.8	2.9
Max	72.9	79.9	93.2	105.1	72.0	115.3	91.2	47.9	96.4
Average	11.4	9.2	16.0	14.8	18.9	26.8	22.4	14.2	23.0
Sum	434.1	388.1	432.9	489.6	490.4	590.2	336.0	312.8	322.4

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	378.2
Channel to Riparian (acres)	428.7
Riparian Encroachment (acres)	**50.5**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	432.2
1950s Floodplain Mapped as 2011 Channel (Ac)	165.3
Total Recruitment (1950s to 2011)(Ac)	**597.4**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	10.3	147.4	113.7	0.0	**271.4**
Acres/Valley Mile	1.3	18.8	14.5	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	91.16	3.23%	25.56	2.82	24.25	30.93

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	247.6	121.5	6.5%
Rip Rap Bottom	82.7	24.2	1.3%
Bluff Pool	148.1	88.7	4.8%
Secondary Channel	110.2	42.9	2.3%
Secondary Channel (Seasonal)	392.6	227.2	12.2%
Channel Crossover	155.4	101.5	5.4%
Point Bar		66.2	3.6%
Side Bar		115.4	6.2%
Mid-channel Bar		82.8	4.4%
Island	768.7	774.6	41.6%
Dry Channel		219.0	11.7%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern | Potential Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
✓	✓	American Robin		✓	Chipping Sparrow			Killdeer	✓	✓	Song Sparrow
✓	✓	American Crow		✓	Clay-collared Sparrow			Lark Bunting		✓	Spotted Sandpiper
✓	✓	American Goldfinch			Cliff Swallow	✓	✓	Lark Sparrow	✓	✓	Spotted Towhee
		American Kestrel	✓	✓	Common Grackle	✓	✓	Lazuli Bunting			Sharp-shinned Hawk
✓	✓	American Redstart			Common Merganser	✓	✓	Least Flycatcher		✓	Swainson's Thrush
✓	✓	Bald Eagle			Common Nighthawk		✓	Mallard			Sandhill Crane
		Baltimore Oriole		✓	Common Raven			Mountain Bluebird	✓	✓	Tree Swallow
✓	✓	Barn Swallow	✓	✓	Common Yellowthroat	✓	✓	Mourning Dove			Turkey Vulture
	✓	Belted Kingfisher			Cooper's Hawk	✓	✓	Northern Flicker			Upland Sandpiper
	✓	Black-billed Cuckoo		✓	Dickcissel			Orchard Oriole		✓	Vesper Sparrow
✓	✓	Black-billed Magpie	✓	✓	Downy Woodpecker		✓	Osprey	✓	✓	Violet-green Swallow
✓	✓	Black-capped Chickadee			Eastern Bluebird		✓	Ovenbird	✓	✓	Warbling Vireo
	✓	Black-and-white Warbler	✓	✓	Eastern Kingbird	✓	✓	Plumbeous Vireo	✓	✓	Western Kingbird
✓	✓	Black-headed Grosbeak			Eurasian Collared-dove	✓	✓	Red-headed Woodpecker	✓	✓	Western Meadowlark
	✓	Blue Jay	✓	✓	European Starling			Red-naped Sapsucker	✓	✓	Western Wood-pewee
		Bobolink	✓	✓	Field Sparrow			Red Crossbill	✓	✓	White-breasted Nuthatch
	✓	Brewer's Blackbird			Franklin's Gull	✓	✓	Ring-necked Pheasant	✓	✓	White-throated Swift
✓	✓	Brown-headed Cowbird			Grasshopper Sparrow	✓	✓	Red-tailed hawk			Wild Turkey
		Brown Creeper	✓	✓	Gray Catbird		✓	Rock Dove	✓	✓	Wood Duck
✓	✓	Brown Thrasher			Great Blue Heron	✓	✓	Red-winged Blackbird			Yellow-bellied Sapsucker
✓	✓	Bullock's Oriole			Great Horned Owl	✓	✓	Red-eyed Vireo			Yellow-billed Cuckoo
	✓	Canada Goose	✓	✓	Hairy Woodpecker			Red-breasted Grosbeak	✓	✓	Yellow-breasted Chat
✓	✓	Cedar Waxwing		✓	House Finch			Say's Phoebe			Yellow-headed Blackbird
	✓	Chimney Swift	✓	✓	House Wren	✓	✓	Savannah Sparrow	✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Yellowstone	**Upstream River Mile**	322.7
Classification	UA: Unconfined anabranching	**Downstream River Mile**	318
General Location	Reed Creek	**Length**	4.70 mi (7.56 km)
General Comments	Meander cutoff isolated by railroad		

Narrative Summary

Reach B9 is located in lower Yellowstone County near Reed Creek. The Reach is 4.7 miles long and is an Unconfined Anabranching (UA) reach type, indicating the presence of extensive forested islands with little valley wall influence on the main channel. This reach type is typically the most dynamic in the system due to a lack of confinement and extent of side channels.

About 7,300 feet of streambank are armored by rock riprap, which is about 15 percent of the total bankline. Most of the bank armor in the reach is protecting the rail line on the south side of the river, and most of it is located along the edge of a section of bluff line. Another section of armor is protecting a major power line crossing on the north bank at RM 321. Currently, two towers on the crossing are right on the edge of the river.

One side channel that is about 8,000 feet long at RM 321.5L was blocked prior to 1950. The lower end of this old channel still holds open water, but the upstream end has been graded into fields and also supports two major power line towers.

Land uses related to both irrigation and the railroad have encroached into the Channel Migration Zone (CMZ) in Reach B9. Overall, land uses in the reach are primarily agricultural, with about 508 acres of flood irrigated land mapped as of 2011. About half of that irrigated acreage is within the CMZ. There are 384 acres under pivot, about 75 of which are within the CMZ. The railroad has encroached into 101 acres of the CMZ and is primarily responsible for its isolation. In total, just under 10 percent of the CMZ has been restricted due to bank armor, and 7.3 percent of the restriction is due to the railroad, while 2.4 percent is associated with the protection of irrigated lands.

The modern 5-year floodplain contains about 76 acres of flood-irrigated ground, and 64 acres of ground under pivot.

Waco-Custer Diversion Dam is located at RM 320. The Waco-Custer ditch company was formed in the early 1900's, and the diversion dam was constructed shortly thereafter (http://www.fws.gov/YellowstoneRiverCoordinator/Waco-custer.html). The Waco-Custer diversion supports approximately 4,300 acres of irrigation, with a diversion capacity of 125 cfs. The structure is located approximately eight miles west of Custer, at River Mile 320. At the diversion, the Yellowstone River flows through two main channels, and the structure itself blocks only the right channel. The structure feeds the Waco-Custer Canal, which flows on the south floodplain surface of the Yellowstone River.

Migration rates in several locations in Reach B9 have exceeded an average of 10 feet per year since the mid-1950s. At Rm 322, the river migrated almost 200 feet between 2001 and 2011, which is double that average rate of 10 feet per year. That rapid recent migration has been through irrigated fields on the south side of the river. Lateral migration of the river has promoted extensive recruitment of new woody riparian habitat. Since the 1950s there has been about 210 acres of riparian recruitment in the reach, most of which was riparian colonization of old 1950's channel area. Additionally, there are 213 mapped wetlands in the reach, including 105 acres of emergent wetland types such as wet meadows and marsh. The reach contains about 53 wetland acres per valley mile, which is a relatively high value for the Yellowstone River.

Reach B9 has had a major loss of forest area that is considered at low risk of cowbird parasitism. In 19590, there were about 48 acres per valley mile of such forest, and that had been reduced by 2001 to 21 acres per valley mile.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 30,200 cfs to 24,500 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,060 cfs to 2,080 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

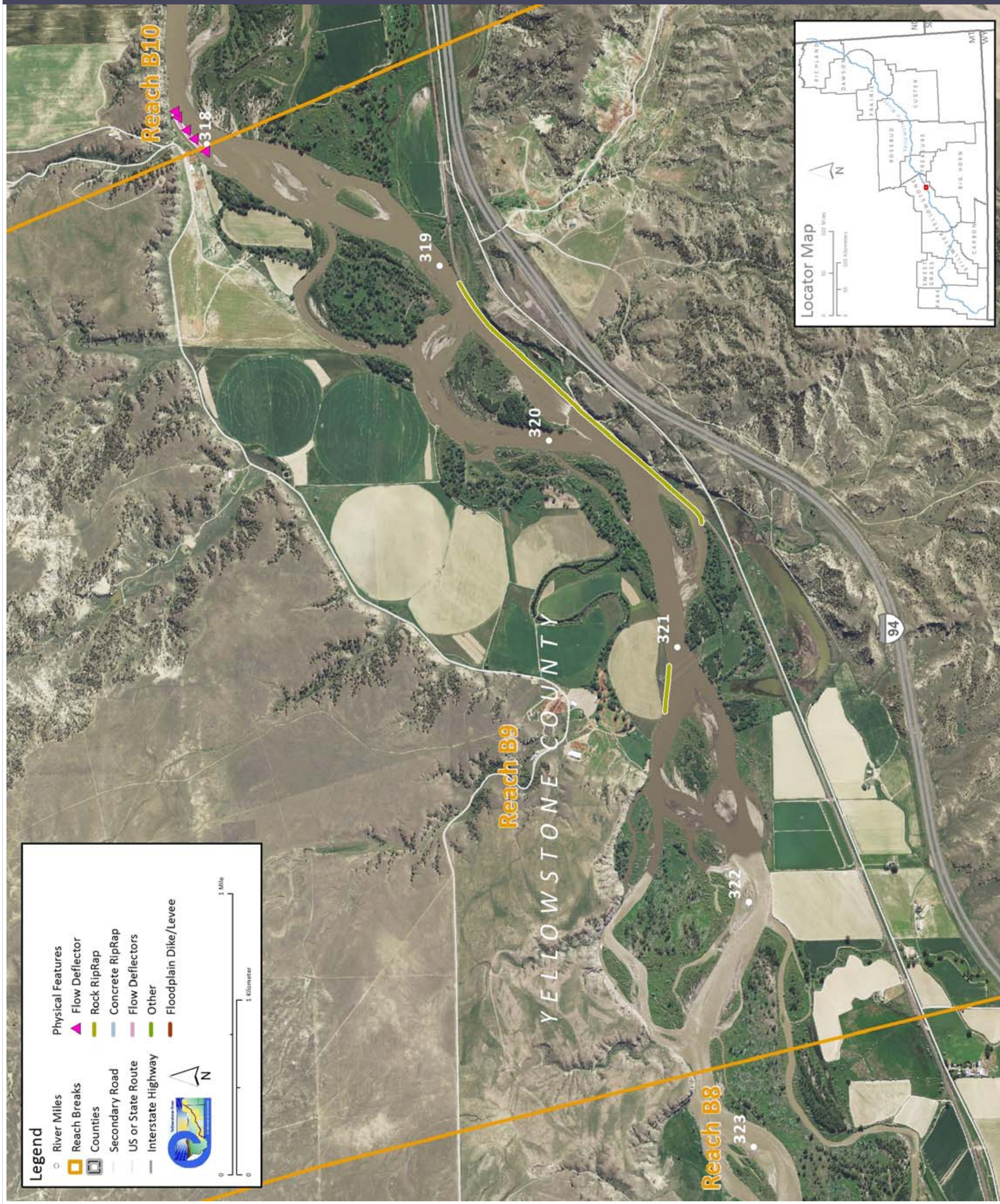
About 23 percent of the 5-year floodplain has become isolated in Reach B9, and the vast majority of this isolation is on the south side of the river at RM 321 where the rail line has isolated an historic side channel. Much of that 5-year floodplain isolation is due to transportation infrastructure on the south side of the river. This isolated floodplain area still holds open water in a distinct swale.

CEA-Related observations in Reach B9 include:
•Blockage of one side channel at RM 321.5 sometime prior to 1950
•Railroad isolation of major channel remnant that supports open water.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B9 include:
•Side channel reactivation at RM 321.5—may be difficult due to power line
•CMZ management due to~10 percent restriction of CMZ
•Russian olive removal
•Floodplain reconnection where active rail line has isolated historic channel remnant at RM 321R.

•Fish passage Practice at Waco Custer Diversion Dam (not complete blockage)
•Watercraft passage Practice at Waco Custer Diversion Dam (side channel passage exists)
•Irrigation Infrastructure management at Waco Custer Diversion Dam.

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	134.0	41.7

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	30,200	55,500	68,100	75,700	91,000	97,200	111,000	3,060	3,846
Regulated	24,500	49,400	62,400	70,400	86,900	93,600	108,800	2,080	2,227
% Change	-18.87%	-10.99%	-8.37%	-7.00%	-4.51%	-3.70%	-1.98%	-32.03%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	NARA	July 9-27, 1950	B/W		6214500	29500
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	29-Jul-96	B/W		6214500	10400
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	14-May-04	Color	16000	6214500	7010
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2009	NAIP	6/29/2009	Color	1-meter pixels	6214500	26200
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/16/2011	Color	1-meter pixels	6214500	36000
2013	NAIP	06/16/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	7,304	14.9%	7,304	14.9%	0
	Flow Deflectors	18	0.0%	18	0.0%	0
	Between Flow Deflectors	70	0.1%	70	0.1%	0
	Feature Type Totals	**7,393**	**15.1%**	**7,393**	**15.1%**	**0**
Floodplain Control						
	Transportation Encroachment	1,748	3.6%	1,748	3.6%	0
	Feature Type Totals	**1,748**	**3.6%**	**1,748**	**3.6%**	**0**
	Reach Totals	**9,141**	**18.6%**	**9,141**	**18.6%**	**0**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	0	0	0	0	0	6,445	0	0
Totals	**0**	**0**	**0**	**0**	**0**	**6,445**	**0**	**0**

Bankline/Floodplain Inventory: Time Series

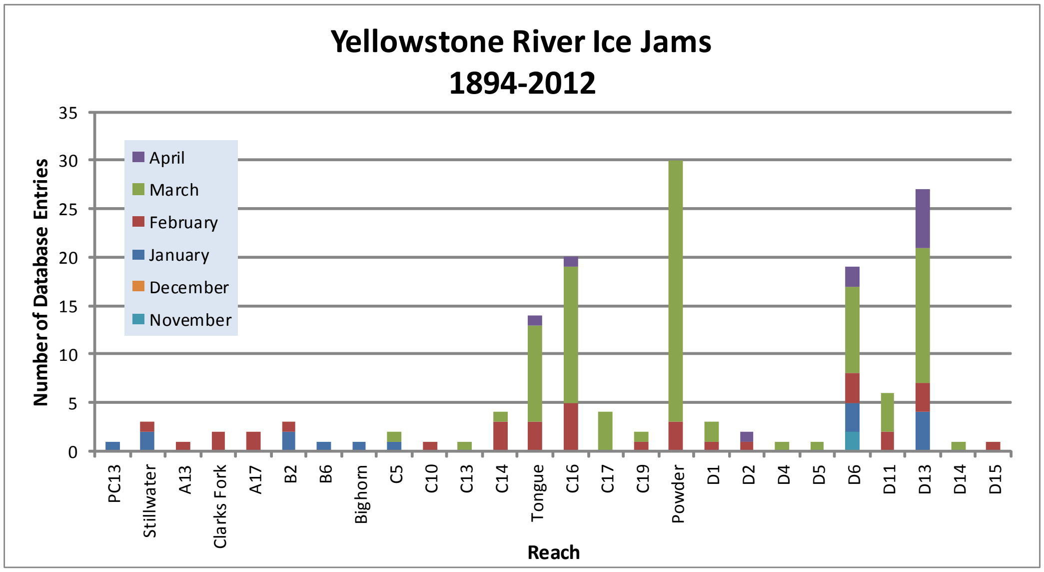
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	In Channel Diversion	198	198	198	198	198	198
	Floodplain Dike/Levee	2,233	2,233	2,233	2,233	2,233	2,233
	Totals	**2,431**	**2,431**	**2,431**	**2,431**	**2,431**	**2,431**
Other							
	Floodplain Dike/Levee	0	173	173	173	173	173
	Totals	**0**	**173**	**173**	**173**	**173**	**173**
Other Off Channel							
	Floodplain Dike/Levee	1,545	1,545	1,545	1,545	1,545	1,545
	Totals	**1,545**	**1,545**	**1,545**	**1,545**	**1,545**	**1,545**
Stream Stabilization							
	Rock RipRap	6,336	6,448	8,229	8,891	8,891	8,891
	Totals	**6,336**	**6,448**	**8,229**	**8,891**	**8,891**	**8,891**
Transportation Encroachment							
	Railroad	14,094	14,094	14,094	14,094	14,094	14,094
	Interstate	0	1,745	1,745	1,745	1,745	1,745

County Road	6,980	6,980	6,980	6,980	6,980	6,980
Totals	**21,074**	**22,819**	**22,819**	**22,819**	**22,819**	**22,819**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	23,025	41,519	2.80	1950 to 1976:	8.46%
1976	22,453	45,810	3.04	1976 to 1995:	-20.71%
1995	24,596	34,695	2.41	1995 to 2001:	7.65%
2001	24,510	39,093	2.59	1950 to 2001:	-7.43%
Change 1950 - 2001	**1,485**	**-2,426**	**-0.21**		

Length of Side Channels Blocked

Pre-1950s (ft)	7,943
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1059		1136	
Total Floodplain Area (Ac)	1059		1311	
Total Isolated (Ac)	**0**	**0.0%**	**175**	**22.7%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	76	0	64	**140**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
525	1,049	1,651	99	6%	82	69	85%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	101	5.8%
RipRap/Flow Deflectors			
	Other Infrastructure	2	0.1%
RipRap			
	Railroad	26	1.5%
	Irrigated	40	2.3%
	Totals	**169**	**9.7%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
232.1	0.0	74.5	0.6	17.5

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	12	31	58	62	0.3%	0.8%	1.5%	1.6%
	Totals	**12**	**31**	**58**	**62**	**0.3%**	**0.8%**	**1.5%**	**1.6%**
Agricultural Land									
	Non-Irrigated	2,250	2,222	1,841	1,805	58.8%	58.1%	48.1%	47.2%
	Irrigated	657	575	923	892	17.2%	15.0%	24.1%	23.3%
	Totals	**2,906**	**2,797**	**2,763**	**2,697**	**75.9%**	**73.1%**	**72.2%**	**70.5%**
Channel									
	Channel	847	845	852	914	22.1%	22.1%	22.3%	23.9%
	Totals	**847**	**845**	**852**	**914**	**22.1%**	**22.1%**	**22.3%**	**23.9%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	1	1	1	1	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**1**	**1**	**1**	**1**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	38	41	41	41	1.0%	1.1%	1.1%	1.1%
	Interstate	0	88	88	88	0.0%	2.3%	2.3%	2.3%
	Railroad	23	23	23	23	0.6%	0.6%	0.6%	0.6%
	Totals	**61**	**153**	**153**	**153**	**1.6%**	**4.0%**	**4.0%**	**4.0%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	384	0.0%	0.0%	0.0%	14.2%	0.0%	0.0%	14.2%	14.2%
	Flood	657	575	923	508	22.6%	20.7%	33.4%	18.8%	-1.9%	12.7%	-14.6%	-3.8%
	Totals	**657**	**575**	**923**	**892**	**22.6%**	**20.7%**	**33.4%**	**33.1%**	**-1.9%**	**12.7%**	**-0.3%**	**10.5%**

Non-Irrigated													
	Multi-Use	1,845	1,691	1,752	1,652	63.5%	60.9%	63.4%	61.3%	-2.6%	2.5%	-2.1%	-2.2%
	Hay/Pasture	405	511	89	153	13.9%	18.4%	3.2%	5.7%	4.5%	-15.2%	2.5%	-8.3%
	Totals	**2,250**	**2,201**	**1,841**	**1,805**	**77.4%**	**79.3%**	**66.6%**	**66.9%**	**1.9%**	**-12.7%**	**0.3%**	**-10.5%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.1	0.4	1.9	0.3	3.5	1.1	0.1	0.0	0.2
Max	33.8	109.4	99.0	100.2	75.8	87.8	41.1	33.8	55.8
Average	6.5	8.8	10.4	19.9	20.5	26.9	15.4	9.9	17.9
Sum	208.0	289.6	270.5	357.8	266.2	269.1	76.9	88.7	161.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	168.9
Channel to Riparian (acres)	175.3
Riparian Encroachment (acres)	**6.4**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	175.8
1950s Floodplain Mapped as 2011 Channel (Ac)	34.9
Total Recruitment (1950s to 2011)(Ac)	**210.7**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	24.3	104.6	83.6	0.0	**212.5**
Acres/Valley Mile	6.2	26.9	21.5	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	5.90	0.27%	0.14	0.58	2.15	1.31

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	**Bankfull**	**Low Flow**	**% of Low Flow**
Scour Pool	164.1	75.4	8.9%
Rip Rap Margin	20.4	11.3	1.3%
Bluff Pool	13.3	6.2	0.7%
Secondary Channel	105.5	22.6	2.7%
Secondary Channel (Seasonal)	85.6	110.1	12.9%
Channel Crossover	127.2	83.4	9.8%
Point Bar		35.4	4.2%
Side Bar		50.6	5.9%
Mid-channel Bar		42.5	5.0%
Island	277.5	317.6	37.3%
Dry Channel		81.6	9.6%
Dam Influenced	16.7	15.0	1.8%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Yellowstone	**Upstream River Mile**	318
Classification	PCM: Partially confined meandering	**Downstream River Mile**	310.8
General Location	Waco	**Length**	7.20 mi (11.59 km)
General Comments	Encroached		

Narrative Summary

Reach B10 is located in lower Yellowstone County and contains the Captain Clark Fishing Access Site. The Reach is 7.2 miles long and is a Partially Confined Meandering reach type, (PCM), indicating the presence of a primary meandering channel thread with substantial valley wall influence on the river. The Captain Clark Fishing Access Site is located in the middle of the reach.

There are about 1,150 feet of rock riprap and 800 feet of flow deflectors in the reach, which collectively armor about 3 percent of the total bankline. About one half of the armor is protecting the active railroad, and the other half is protecting agricultural land. High resolution 2011 imagery shows the complete flanking of the mapped flow deflectors since 2001. The river has since eroded over 100 feet of bank behind the flanked barbs, eroding into a series of old corrals. The barbs are readily visible in the river.

One abandoned side channel that is about 3,300 feet long at RM 315R appears to be very old, however has several crossings that currently form plugs along its course. The channel is still within the 5-year floodplain, so the plugs have likely affected its function as a flood channel, and perhaps historically as a seasonal channel. This historic side channel is located landward (south) of the Fishing Access Site, which is on an old island. The lower end of this old channel supports a high density of Russian olive.

Reach B10 has lost almost 5.5 miles of side channel length since 1950. In the uppermost portion of the reach, the main river channel flipped from the south side of the corridor to the north sometime between 1976 and 2001, progressively abandoning a mile long channel and focusing the river into a single thread that flows along the north valley bluff line. This is where the flow deflectors described above have been flanked. This pattern has been common all through the reach; major secondary channels from the 1950s have been abandoned and the river has shifted to much more of a single thread meandering river. Some of the 1950’s channels have potentially been blocked, and others appear to have been passively abandoned.

On the south side of the river at RM 312.5, the rail line currently isolates about 42 acres of historic 100-year floodplain. The river is currently against the rail line at this location, so that the separation between the river and the isolated remnant is only about 200 feet. This area is also adjacent to about 20 acres of mapped emergent wetland.

Overall, land uses in reach B10 are primarily agricultural, with about 860 acres of flood irrigated land mapped as of 2011. About one third of that irrigated acreage is within the CMZ. The railroad has encroached into 19 acres of the CMZ. In total, just under 7 percent of the CMZ has been restricted, and all of that restriction is due to bank armor protecting the rail line.

The modern 5-year floodplain contains about 72acres of flood-irrigated ground. Reach B10 also supports almost 40 acres of mapped wetlands per valley mile, which is a relatively high density for the corridor.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 30,200 cfs to 24,500 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,070 cfs to 2,090 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B10 include:
•Active and passive abandonment of over five miles of anabranching channel length since 1950
•Bank armor flanking associated with flow consolidation into single thread.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B10 include:
•Removal of flanked flow deflectors at RM 318
•Side channel reactivation throughout reach
•Floodplain reconnection at Rm 312.5R
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	126.8	46.4

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	30,200	55,500	68,100	75,700	91,000	97,200	111,000	3,070	3,846
Regulated	24,500	49,400	62,400	70,400	86,900	93,600	108,800	2,090	2,227
% Change	-18.87%	-10.99%	-8.37%	-7.00%	-4.51%	-3.70%	-1.98%	-31.92%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	NARA	July 9-27, 1950	B/W		6214500	29500
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	7/29/1996 - 8/26/96 - 8/19/96	B/W		6214500	10400
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	14-May-04	Color	1:15,840	6214500	7010
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2009	NAIP	6/29/2009	Color	1-meter pixels	6214500	26200
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/16/2011	Color	1-meter pixels	6214500	36000
2013	NAIP	06/16/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	1,153	1.5%	1,153	1.5%	0
	Flow Deflectors	194	0.3%	194	0.3%	0
	Between Flow Deflectors	613	0.8%	613	0.8%	0
	Feature Type Totals	**1,960**	**2.6%**	**1,960**	**2.6%**	**0**
Floodplain Control						
	Transportation Encroachment	6,439	8.5%	6,439	8.5%	0
	Feature Type Totals	**6,439**	**8.5%**	**6,439**	**8.5%**	**0**
	Reach Totals	**8,399**	**11.0%**	**8,399**	**11.0%**	**0**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	0	0	895	0	0	0	0	0
Rock RipRap	0	0	0	0	0	656	0	0
Totals	**0**	**0**	**895**	**0**	**0**	**656**	**0**	**0**

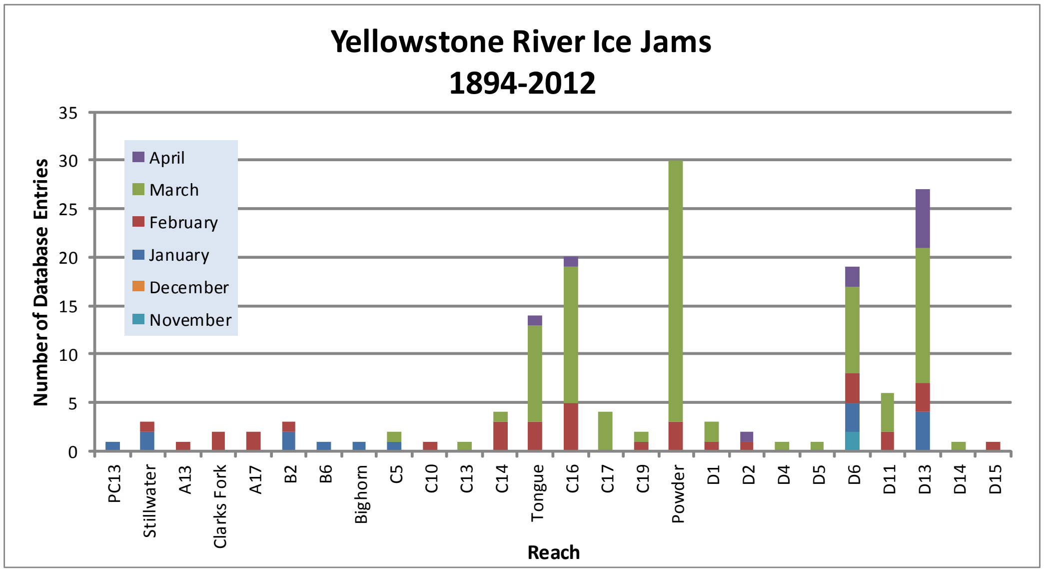
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Stream Stabilization							
	Rock RipRap	1,048	1,956	2,172	2,172	2,172	2,172
	Flow Deflector	0	0	0	742	2,131	2,131
	Concrete RipRap	0	0	255	255	255	255
	Totals	**1,048**	**1,956**	**2,427**	**3,169**	**4,558**	**4,558**
Transportation Encroachment							
	Railroad	20,661	20,661	20,661	20,661	20,661	20,661
	Interstate	0	9,540	9,540	9,540	9,540	9,540
	County Road	19,403	19,403	19,403	19,403	19,403	19,403
	Totals	**40,064**	**49,605**	**49,605**	**49,605**	**49,605**	**49,605**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	36,593	55,863	2.53	1950 to 1976:	-24.62%
1976	39,622	35,840	1.90	1976 to 1995:	12.29%
1995	37,698	42,926	2.14	1995 to 2001:	-19.85%
2001	38,094	27,208	1.71	1950 to 2001:	-32.15%
Change 1950 - 2001	**1,501**	**-28,655**	**-0.81**		

Length of Side Channels Blocked

Pre-1950s (ft)	3,344
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	112	6.5%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1595		1648	
Total Floodplain Area (Ac)	1707		1850	
Total Isolated (Ac)	**112**	**6.5%**	**202**	**18.7%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	72	0	0	**72**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
668	1,336	2,332	164	7%	50	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	159	6.7%
RipRap/Flow Deflectors			
	Other Infrastructure	5	0.2%
	Totals	**164**	**6.9%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
323.6	0.0	0.0	0.0	18.7

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	44	54	56	58	0.8%	1.0%	1.0%	1.1%
	Totals	**44**	**54**	**56**	**58**	**0.8%**	**1.0%**	**1.0%**	**1.1%**
Agricultural Land									
	Non-Irrigated	3,565	3,487	3,387	3,406	64.6%	63.2%	61.3%	61.7%
	Irrigated	637	749	909	858	11.5%	13.6%	16.5%	15.5%
	Totals	**4,202**	**4,236**	**4,296**	**4,264**	**76.1%**	**76.7%**	**77.8%**	**77.2%**
Channel									
	Channel	1,220	1,060	992	1,021	22.1%	19.2%	18.0%	18.5%
	Totals	**1,220**	**1,060**	**992**	**1,021**	**22.1%**	**19.2%**	**18.0%**	**18.5%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	2	8	8	0.0%	0.0%	0.1%	0.1%
	Totals	**0**	**2**	**8**	**8**	**0.0%**	**0.0%**	**0.1%**	**0.1%**
Transportation									
	Public Road	18	41	41	41	0.3%	0.7%	0.7%	0.7%
	Interstate	0	93	93	93	0.0%	1.7%	1.7%	1.7%
	Railroad	36	36	36	36	0.7%	0.7%	0.7%	0.7%
	Totals	**55**	**170**	**170**	**170**	**1.0%**	**3.1%**	**3.1%**	**3.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	637	749	909	858	15.2%	17.7%	21.2%	20.1%	2.5%	3.5%	-1.0%	5.0%
	Totals	**637**	**749**	**909**	**858**	**15.2%**	**17.7%**	**21.2%**	**20.1%**	**2.5%**	**3.5%**	**-1.0%**	**5.0%**

Non-Irrigated												
Multi-Use	3,089	2,948	3,006	2,985	73.5%	69.6%	70.0%	70.0%	-3.9%	0.4%	0.0%	-3.5%
Hay/Pasture	476	539	381	421	11.3%	12.7%	8.9%	9.9%	1.4%	-3.9%	1.0%	-1.5%
Totals	**3,565**	**3,487**	**3,387**	**3,406**	**84.8%**	**82.3%**	**78.8%**	**79.9%**	**-2.5%**	**-3.5%**	**1.0%**	**-5.0%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.0	0.2	0.4	0.0	1.4	1.8	0.8	1.6	5.3
Max	54.3	35.8	115.1	64.0	30.8	75.1	138.5	76.0	45.7
Average	8.1	7.8	19.2	15.8	12.8	27.3	16.2	19.0	17.5
Sum	276.3	321.3	422.2	427.9	166.8	327.2	226.1	304.3	157.7

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	230.5
Channel to Riparian (acres)	237.2
Riparian Encroachment (acres)	**6.7**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	244.2
1950s Floodplain Mapped as 2011 Channel (Ac)	170.4
Total Recruitment (1950s to 2011)(Ac)	**414.5**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	19.7	113.2	106.4	0.0	**239.3**
Acres/Valley Mile	3.3	18.9	17.8	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	38.82	1.47%	5.14	0.78	10.00	3.84

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	125.7	63.8	6.4%
Rip Rap Bottom	50.1	24.1	2.4%
Bluff Pool	329.4	145.6	14.7%
Secondary Channel (Seasonal)	163.8	145.2	14.6%
Channel Crossover	100.5	79.4	8.0%
Point Bar		54.4	5.5%
Side Bar		41.1	4.1%
Mid-channel Bar		62.7	6.3%
Island	222.3	222.3	22.4%
Dry Channel		153.0	15.4%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern

Potential Species of Concern

Reach	Region	
✓	✓	American Robin
✓	✓	American Crow
✓	✓	American Goldfinch
		American Kestrel
	✓	American Redstart
	✓	Bald Eagle
		Baltimore Oriole
	✓	Barn Swallow
✓	✓	Belted Kingfisher
	✓	Black-billed Cuckoo
	✓	Black-billed Magpie
	✓	Black-capped Chickadee
	✓	Black-and-white Warbler
	✓	Black-headed Grosbeak
	✓	Blue Jay
		Bobolink
	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
		Brown Creeper
	✓	Brown Thrasher
	✓	Bullock's Oriole
	✓	Canada Goose
✓	✓	Cedar Waxwing
	✓	Chimney Swift
	✓	Chipping Sparrow
	✓	Clay-collared Sparrow
		Cliff Swallow
	✓	Common Grackle
		Common Merganser
		Common Nighthawk
✓	✓	Common Raven
✓	✓	Common Yellowthroat
		Cooper's Hawk
	✓	Dickcissel
	✓	Downy Woodpecker
		Eastern Bluebird
	✓	Eastern Kingbird
		Eurasian Collared-dove
✓	✓	European Starling
	✓	Field Sparrow
		Franklin's Gull
		Grasshopper Sparrow
	✓	Gray Catbird
		Great Blue Heron
		Great Horned Owl
	✓	Hairy Woodpecker
	✓	House Finch
✓	✓	House Wren
		Killdeer
		Lark Bunting
	✓	Lark Sparrow
	✓	Lazuli Bunting
	✓	Least Flycatcher
	✓	Mallard
		Mountain Bluebird
	✓	Mourning Dove
	✓	Northern Flicker
		Orchard Oriole
	✓	Osprey
	✓	Ovenbird
	✓	Plumbeous Vireo
	✓	Red-headed Woodpecker
		Red-naped Sapsucker
		Red Crossbill
✓	✓	Ring-necked Pheasant
	✓	Red-tailed hawk
	✓	Rock Dove
	✓	Red-winged Blackbird
	✓	Red-eyed Vireo
		Red-breasted Grosbeak
		Say's Phoebe
	✓	Savannah Sparrow
✓	✓	Song Sparrow
	✓	Spotted Sandpiper
	✓	Spotted Towhee
		Sharp-shinned Hawk
	✓	Swainson's Thrush
		Sandhill Crane
	✓	Tree Swallow
		Turkey Vulture
		Upland Sandpiper
	✓	Vesper Sparrow
	✓	Violet-green Swallow
	✓	Warbling Vireo
	✓	Western Kingbird
	✓	Western Meadowlark
	✓	Western Wood-pewee
	✓	White-breasted Nuthatch
	✓	White-throated Swift
		Wild Turkey
	✓	Wood Duck
		Yellow-bellied Sapsucker
		Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
		Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Yellowstone	**Upstream River Mile**	310.8
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	302.7
General Location	To Custer Bridge	**Length**	8.10 mi (13.04 km)
General Comments	To Custer Bridge		

Narrative Summary

Reach B11 is located in lower Yellowstone County. The Reach is 8.1 miles long and is a Partially Confined Anabranching reach type, (PCA), indicating the presence of forested islands with substantial valley wall influence on the river. Custer Bridge and the town of Bighorn are at the lower end of the reach.

There are about 2,600 feet of rock riprap and 1,200 feet of flow deflectors in the reach, which collectively armors about 4 percent of the total bankline. All of the armor is protecting agricultural land, both irrigated and non-irrigated. Most of the rock riprap was built between 1950 and 1976, whereas the flow deflectors were built between 1995 and 2001.

One side channel that is about 1,000 feet long at RM 305R appears to have been blocked as a seasonal channel by three different plugs that were all in place in 1950. Hydraulic modeling results show that under undeveloped conditions, the channel conveyed water at a 2-year discharge, but now it doesn't convey flow at the 5-year discharge. The blocked channel now has dense stands of Russian olive on its lower end.

Since 1950, the bankfull area of the channel has increased by about 60 acres in Reach B11 indicating some enlargement of the main channel between 1950 and 2001. This is interesting because there was also a net increase in riparian area due to erosional processes of about 75 acres, which may appear contradictory. In reviewing the GIS data, it is apparent that much of the channel migration in Reach B11 was through unvegetated farm fields such that the channel was able to enlarge, and the area created by the migration was then colonized by riparian vegetation, resulting in a net gain in riparian area, along with an increase in overall channel size. The total riparian recruitment acreage in the reach was 483 acres; 334 of those acres of recruitment were in 1950s channel areas, and 149 acres of eroded floodplain have been colonized by woody riparian species. The increase in riparian area is most evidenced by riparian shrub, which increased from 219 acres in 1950 to 462 acres in 2001. Reach B11 consequently has a robust riparian corridor with active recruitment associated with channel migration.

Reach B11 experienced a major avulsion between 1976 and 1002, when the river jumped about 1,600 feet to the northwest between RM 305 and RM 306, relocating into a relatively small developing side channel. The avulsed channel has since been migrating back to the southeast, creating a large sediment deposit downstream at RM 305 where the river corridor is tightly confined by the valley wall to the northwest and bank armored fields to the southeast. This section of river appears quite unstable.

Most of the floodplain isolation has been related to more frequent flooding; whereas 2 percent of the 100-year floodplain has become isolated due to human development, about 17 percent of the 5-year floodplain is no longer inundated at that frequency. Much of the loss of 5-year floodplain was in the blocked channel at RM 305R described above. The 100-year isolated floodplain is behind the active rail line and Interstate about 1,000 feet south of the river at RM 308.5R. Emergent wetlands have been mapped in this isolated floodplain area, which is about 21 acres in size. Hydraulic modeling indicates that this area would also be inundated at a 5-year event, making it a good potential candidate for restoring floodplain connectivity through the rail line and frontage road, or for simple wetland restoration.

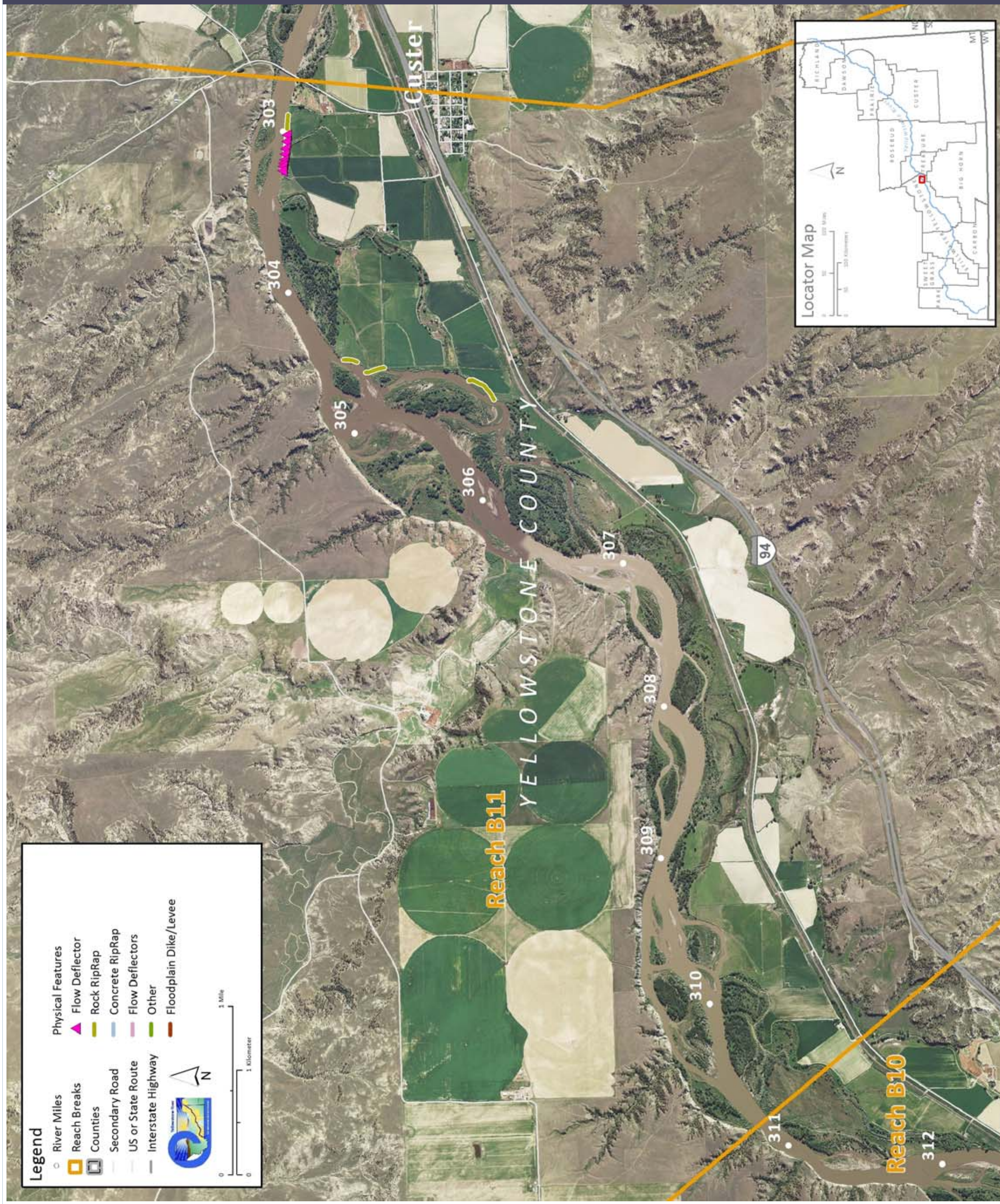
The mapped land uses in Reach B11 indicate that flood irrigation is the dominant land use, with about 1,500 acres of ground in flood irrigation and 100 in pivot. The town of Bighorn contributes to about 70 acres of urban/exurban development, and the proximity of the rail line to the river corridor is evidenced by 191 acres of transportation footprint. The most common developed land use in the Channel Migration Zone (CMZ) is flood irrigation (431 acres). About 17 percent of the CMZ has been isolated due to physical features such as bank armor and floodplain dikes, and most of that is riprap protection against irrigated lands (11 percent of CMZ). Most of these restrictions are in the lower reach near the town of Bighorn.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 30,200 cfs to 24,500 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,080 cfs to 2,100 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B11 include:
•Side channel blockage prior to 1950
•Channel instability caused by avulsion at RM 305

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B11 include:
•Side channel reactivation at RM 305R
•Floodplain reconnection at Rm 308.5R
•Russian olive removal
•Channel Migration Zone (CMZ) management due to extent of CMZ restricted (17 percent)

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	118.7	53.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	30,200	55,500	68,100	75,700	91,000	97,200	111,000	3,080	3,846
Regulated	24,500	49,400	62,400	70,400	86,900	93,600	108,800	2,100	2,227
% Change	-18.87%	-10.99%	-8.37%	-7.00%	-4.51%	-3.70%	-1.98%	-31.82%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	NARA	July 9-27, 1950	B/W		6214500	29500
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	19-Aug-96	B/W		6214500	5320
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	14-May-04	Color	1:15,840	6214500	7010
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2009	NAIP	6/29/2009	Color	1-meter pixels	6214500	26200
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/16/2011	Color	1-meter pixels	6214500	36000
2013	NAIP	06/16/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	2,570	3.0%	2,570	3.0%	0
	Flow Deflectors	395	0.5%	395	0.5%	0
	Between Flow Deflectors	774	0.9%	774	0.9%	0
	Feature Type Totals	**3,740**	**4.4%**	**3,740**	**4.4%**	**0**
	Reach Totals	**3,740**	**4.4%**	**3,740**	**4.4%**	**0**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	1,168	0	0	0	0	0	0	0
Rock RipRap	597	1,975	0	0	0	0	0	0
Totals	**1,765**	**1,975**	**0**	**0**	**0**	**0**	**0**	**0**

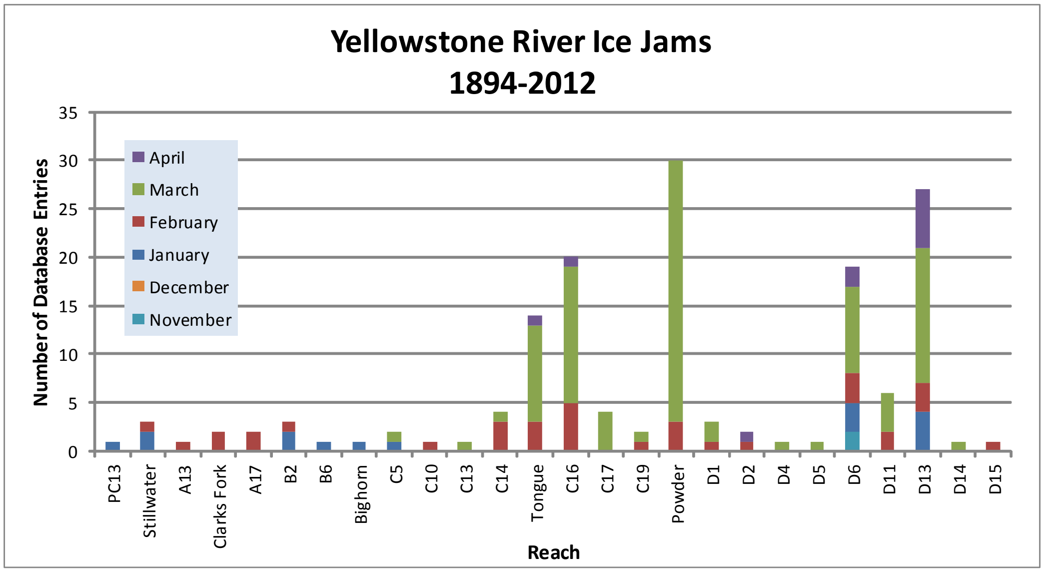
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Other Off Channel							
	Floodplain Dike/Levee	2,005	2,005	2,005	2,005	2,005	2,005
	Totals	**2,005**	**2,005**	**2,005**	**2,005**	**2,005**	**2,005**
Stream Stabilization							
	Rock RipRap	0	4,133	5,643	6,103	6,103	6,103
	Flow Deflector	0	0	0	939	939	939
	Totals	**0**	**4,133**	**5,643**	**7,042**	**7,042**	**7,042**
Transportation Encroachment							
	Railroad	12,691	12,691	12,691	12,691	12,691	12,691
	County Road	11,967	11,967	11,967	11,967	11,967	11,967
	Bridge Approach	3,362	3,362	3,362	3,362	3,362	3,362
	Totals	**28,020**	**28,020**	**28,020**	**28,020**	**28,020**	**28,020**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	43,911	64,157	2.46	1950 to 1976:	-3.81%
1976	44,567	60,938	2.37	1976 to 1995:	5.48%
1995	42,397	63,466	2.50	1995 to 2001:	3.63%
2001	42,826	67,992	2.59	1950 to 2001:	5.14%
Change 1950 - 2001	**-1,085**	**3,834**	**0.13**		

Length of Side Channels Blocked

Pre-1950s (ft)	1,002
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	33	1.9%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1743		1989	
Total Floodplain Area (Ac)	1777		2195	
Total Isolated (Ac)	**33**	**1.9%**	**206**	**16.9%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	74	0	0	**74**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
607	1,214	2,820	309	11%	228	203	89%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	98	3.2%
	Public Road	1	0.0%
RipRap/Flow Deflectors			
	Irrigated	88	2.9%
RipRap			
	Irrigated	325	10.7%
	Totals	**511**	**16.8%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
431.0	0.0	0.0	1.0	24.5

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	54	62	70	74	0.8%	0.9%	1.0%	1.1%
	Totals	**54**	**62**	**70**	**74**	**0.8%**	**0.9%**	**1.0%**	**1.1%**
Agricultural Land									
	Non-Irrigated	3,927	3,508	3,334	3,348	57.8%	51.6%	49.1%	49.3%
	Irrigated	1,190	1,538	1,685	1,592	17.5%	22.6%	24.8%	23.4%
	Totals	**5,117**	**5,046**	**5,018**	**4,941**	**75.3%**	**74.3%**	**73.9%**	**72.7%**
Channel									
	Channel	1,462	1,444	1,456	1,516	21.5%	21.3%	21.4%	22.3%
	Totals	**1,462**	**1,444**	**1,456**	**1,516**	**21.5%**	**21.3%**	**21.4%**	**22.3%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	6	20	0.0%	0.0%	0.1%	0.3%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	2	4	5	5	0.0%	0.1%	0.1%	0.1%
	Totals	**2**	**4**	**11**	**25**	**0.0%**	**0.1%**	**0.2%**	**0.4%**
Transportation									
	Public Road	49	48	48	48	0.7%	0.7%	0.7%	0.7%
	Interstate	0	104	104	104	0.0%	1.5%	1.5%	1.5%
	Railroad	39	39	39	39	0.6%	0.6%	0.6%	0.6%
	Totals	**88**	**191**	**191**	**191**	**1.3%**	**2.8%**	**2.8%**	**2.8%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	26	26	26	26	0.4%	0.4%	0.4%	0.4%
	Urban Commercial	21	19	19	19	0.3%	0.3%	0.3%	0.3%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	21	0	0	0	0.3%	0.0%	0.0%	0.0%
	Totals	**68**	**45**	**45**	**45**	**1.0%**	**0.7%**	**0.7%**	**0.7%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	37	99	102	0.0%	0.7%	2.0%	2.1%	0.7%	1.2%	0.1%	2.1%
	Flood	1,190	1,501	1,586	1,491	23.3%	29.8%	31.6%	30.2%	6.5%	1.8%	-1.4%	6.9%
	Totals	**1,190**	**1,538**	**1,685**	**1,592**	**23.3%**	**30.5%**	**33.6%**	**32.2%**	**7.2%**	**3.1%**	**-1.3%**	**9.0%**

Non-Irrigated												
Multi-Use	3,091	3,010	3,110	2,772	60.4%	59.6%	62.0%	56.1%	-0.8%	2.3%	-5.9%	-4.3%
Hay/Pasture	836	498	223	577	16.3%	9.9%	4.5%	11.7%	-6.5%	-5.4%	7.2%	-4.7%
Totals	**3,927**	**3,508**	**3,334**	**3,348**	**76.7%**	**69.5%**	**66.4%**	**67.8%**	**-7.2%**	**-3.1%**	**1.3%**	**-9.0%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.4	0.2	0.5	0.6	0.6	1.1	1.3	6.5	5.0
Max	31.0	34.1	85.4	122.4	92.9	86.6	51.4	27.6	53.5
Average	6.5	8.4	14.9	18.0	19.0	28.1	8.9	14.2	21.5
Sum	219.3	319.5	462.4	504.7	531.0	422.1	169.4	155.7	215.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	255.2
Channel to Riparian (acres)	329.7
Riparian Encroachment (acres)	**74.5**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	334.4
1950s Floodplain Mapped as 2011 Channel (Ac)	149.3
Total Recruitment (1950s to 2011)(Ac)	**483.7**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	17.6	160.7	43.0	0.0	**221.4**
Acres/Valley Mile	2.4	21.8	5.8	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	30.62	0.85%	1.45	3.23	12.87	2.88

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	286.3	192.2	13.2%
Rip Rap Bottom	17.0	12.7	0.9%
Bluff Pool	89.0	31.0	2.1%
Secondary Channel	49.8	33.7	2.3%
Secondary Channel (Seasonal)	384.2	176.3	12.1%
Channel Crossover	150.0	115.4	7.9%
Point Bar		37.3	2.6%
Side Bar		99.9	6.9%
Mid-channel Bar		75.3	5.2%
Island	479.7	479.7	32.9%
Dry Channel		202.5	13.9%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.

There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Yellowstone	**Upstream River Mile**	302.7
Classification	UA: Unconfined anabranching	**Downstream River Mile**	298.1
General Location	To Bighorn River confluence	**Length**	4.60 mi (7.40 km)
General Comments	to Bighorn River confluence		

Narrative Summary

Reach B12 is located in lowermost Yellowstone County and extends to the mouth of the Bighorn River. The Reach is 4.6 miles long and is an Unconfined Anabranching reach type, (UA), indicating the presence of forested islands with minimal valley wall influence on the river. These reach types tend to be the most dynamic of all reach types, with typically high rates of bank migration.

There are about 7,800 feet of rock riprap in the reach, which collectively armors about 16 percent of the total bankline. Most of the armor (7,700 feet) is protecting the rail line, with the remainder protecting non-irrigated agricultural land. At two locations (RM 301.5 and RM 299), the river is flowing along bank armor that is right on the railroad prism. One segment of bank armor right at the Bighorn River confluence is actively flanking and will likely be eroded out shortly. Most of the rock riprap was in place in 1950. About 3 miles of transportation encroachment due to the railroad was mapped in the reach.

No blocked side channels have been mapped in Reach B12.

Floodplain turnover rates have dropped in this reach, from 1.9 acres/year/valley mile between 1950 and 1976 to 1.3 acres/year/valley mile between 1976 and 2001. Between 1950 and 2001, there was a total of 214 acres of riparian recruitment in the reach, most of which was colonization of area that was channel in 1950.

Whereas 9 percent of the 100-year floodplain has become isolated due to human development, about 21 percent of the 5-year floodplain is no longer inundated at that frequency. All of the 100-year floodplain isolation is due to the railroad. These areas are very proximal to the river at RM 299 and 302, and could potentially be considered for floodplain and/or wetland restoration.

Land use is dominated by agriculture, with 137 acres of pivot irrigation development since 1950. Almost 50 of those acres of pivot are within the Channel Migration Zone (CMZ). Almost 9 percent of the Channel Migration Zone (CMZ) has been restricted, and the vast majority of that restriction is due to rock riprap protection of the railroad (8 percent).

Reach B12 supports 144 acres of wetland, which at over 35 acres per valley mile is a relatively high concentration of wetlands on the river. There are also 33 acres of mapped Russian olive.

Contrary to most other Reaches, Reach B11 has seen an increase in forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 33 acres per valley mile of such forest, and that number increased to 36 acres per valley mile by 2001.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 30,200 cfs to 24,500 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,090 cfs to 2,100 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B12 include:
•Active flanking of bank armor at mouth of Bighorn River
•Channel instability caused by avulsion at RM 305

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B12 include:
•Bank armor maintenance where active flanking is occurring at mouth of Bighorn River at RM 298.3R
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	114.1	61.7

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	30,200	55,500	68,100	75,700	91,000	97,200	111,000	3,090	3,846
Regulated	24,500	49,400	62,400	70,400	86,900	93,600	108,800	2,100	2,227
% Change	-18.87%	-10.99%	-8.37%	-7.00%	-4.51%	-3.70%	-1.98%	-32.04%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	NARA	July 9-27, 1950	B/W		6214500	29500
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	8/19/96 - 8/8/96	B/W		6214500	5320
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	14-May-04	Color	1:15,840	6214500	7010
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2005	NAIP	07/13/2005	color	1-meter pixels	6214500	11100
2009	NAIP	6/29/2009	Color	1-meter pixels	6214500	26200
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/20/2011	Color	1-meter pixels	6214500	30500
2011	NAIP	7/16/2011	Color	1-meter pixels	6214500	36000
2013	NAIP	06/16/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	7,778	16.2%	7,778	16.2%	0
	Feature Type Totals	**7,778**	**16.2%**	**7,778**	**16.2%**	**0**
Floodplain Control						
	Transportation Encroachment	15,641	32.5%	15,641	32.5%	0
	Feature Type Totals	**15,641**	**32.5%**	**15,641**	**32.5%**	**0**
	Reach Totals	**23,420**	**48.7%**	**23,420**	**48.7%**	**0**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	0	1,227	0	0	0	7,698	0	0
Totals	**0**	**1,227**	**0**	**0**	**0**	**7,698**	**0**	**0**

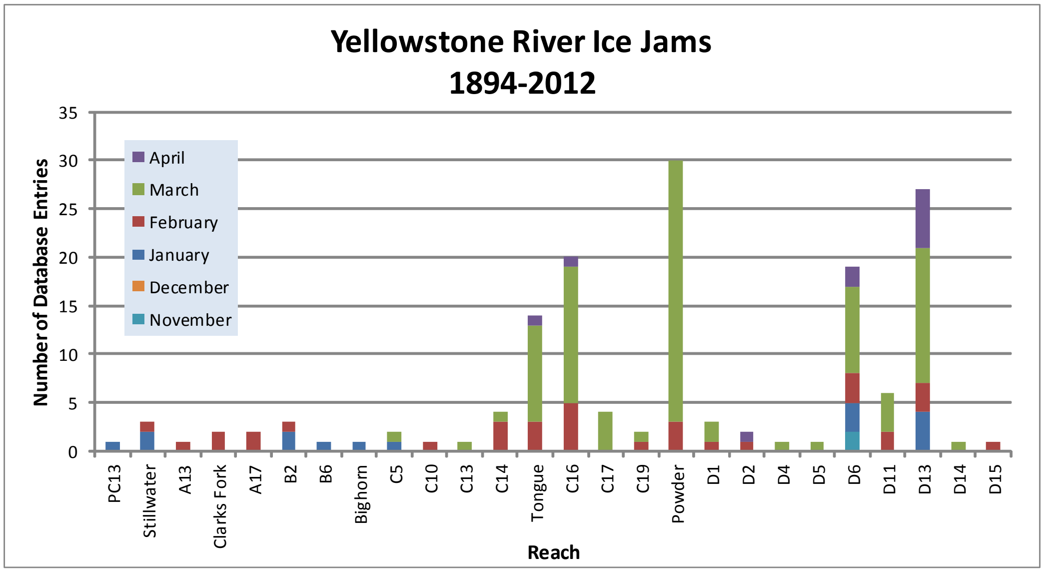
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Other Off Channel							
	Floodplain Dike/Levee	987	987	987	987	987	987
	Totals	**987**	**987**	**987**	**987**	**987**	**987**
Stream Stabilization							
	Rock RipRap	7,346	8,666	9,392	10,182	10,182	10,182
	Totals	**7,346**	**8,666**	**9,392**	**10,182**	**10,182**	**10,182**
Transportation Encroachment							
	Railroad	15,096	15,096	15,096	15,096	15,096	15,096
	Interstate	0	3,548	3,548	3,548	3,548	3,548
	Bridge Approach	562	562	562	562	562	562
	Totals	**15,658**	**19,206**	**19,206**	**19,206**	**19,206**	**19,206**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	23,947	47,793	3.00
1976	23,530	42,157	2.79
1995	23,760	43,470	2.83
2001	24,028	44,502	2.85
Change 1950 - 2001	**81**	**-3,291**	**-0.14**

	% Change in Braiding
1950 to 1976:	-6.81%
1976 to 1995:	1.36%
1995 to 2001:	0.80%
1950 to 2001:	-4.80%

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	90	8.7%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	937		1097	
Total Floodplain Area (Ac)	1027		1239	
Total Isolated (Ac)	**90**	**8.7%**	**142**	**20.7%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	6	**6**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
381	761	1,654	147	9%	17	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	12	0.7%
RipRap			
	Railroad	134	8.0%
	Totals	**147**	**8.8%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
102.9	0.0	48.5	0.0	19.4

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	11	21	31	43	0.3%	0.5%	0.8%	1.1%
	Totals	**11**	**21**	**31**	**43**	**0.3%**	**0.5%**	**0.8%**	**1.1%**
Agricultural Land									
	Non-Irrigated	2,487	2,327	2,198	2,112	61.8%	57.8%	54.6%	52.5%
	Irrigated	498	522	676	693	12.4%	13.0%	16.8%	17.2%
	Totals	**2,985**	**2,848**	**2,874**	**2,805**	**74.2%**	**70.8%**	**71.4%**	**69.7%**
Channel									
	Channel	955	1,011	976	1,033	23.7%	25.1%	24.2%	25.7%
	Totals	**955**	**1,011**	**976**	**1,033**	**23.7%**	**25.1%**	**24.2%**	**25.7%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	35	39	39	39	0.9%	1.0%	1.0%	1.0%
	Interstate	0	65	65	65	0.0%	1.6%	1.6%	1.6%
	Railroad	25	25	25	25	0.6%	0.6%	0.6%	0.6%
	Totals	**60**	**130**	**130**	**130**	**1.5%**	**3.2%**	**3.2%**	**3.2%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	4	4	4	4	0.1%	0.1%	0.1%	0.1%
	Urban Commercial	11	11	11	11	0.3%	0.3%	0.3%	0.3%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**15**	**15**	**15**	**15**	**0.4%**	**0.4%**	**0.4%**	**0.4%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	15	137	0.0%	0.0%	0.5%	4.9%	0.0%	0.5%	4.4%	4.9%
	Flood	498	522	661	556	16.7%	18.3%	23.0%	19.8%	1.6%	4.7%	-3.2%	3.1%
	Totals	**498**	**522**	**676**	**693**	**16.7%**	**18.3%**	**23.5%**	**24.7%**	**1.6%**	**5.2%**	**1.2%**	**8.0%**

Non-Irrigated												
Multi-Use	2,053	2,033	2,029	1,944	68.8%	71.4%	70.6%	69.3%	2.6%	-0.8%	-1.3%	0.5%
Hay/Pasture	434	294	170	168	14.5%	10.3%	5.9%	6.0%	-4.2%	-4.4%	0.1%	-8.5%
Totals	**2,487**	**2,327**	**2,198**	**2,112**	**83.3%**	**81.7%**	**76.5%**	**75.3%**	**-1.6%**	**-5.2%**	**-1.2%**	**-8.0%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.5	0.7	0.6	3.2	0.8	0.6	0.0	0.5	0.3
Max	62.3	49.2	66.6	91.5	131.1	56.8	30.5	47.0	112.3
Average	10.4	7.7	13.9	25.2	30.7	17.3	9.7	9.0	26.0
Sum	198.4	199.8	333.3	226.5	276.3	190.5	115.9	126.4	182.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	138.5
Channel to Riparian (acres)	206.1
Riparian Encroachment (acres)	**67.6**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	197.2
1950s Floodplain Mapped as 2011 Channel (Ac)	17.3
Total Recruitment (1950s to 2011)(Ac)	**214.5**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	5.6	104.4	34.3	0.0	**144.3**
Acres/Valley Mile	1.5	27.8	9.1	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	32.54	1.56%	0.42	1.66	12.52	10.02

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	179.4	99.9	10.2%
Rip Rap Bottom	64.0	10.2	1.0%
Secondary Channel	31.8	19.4	2.0%
Secondary Channel (Seasonal)	228.1	144.2	14.8%
Channel Crossover	60.9	54.1	5.5%
Point Bar		13.5	1.4%
Side Bar		58.4	6.0%
Mid-channel Bar		37.4	3.8%
Island	423.1	423.1	43.4%
Dry Channel		115.7	11.9%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Treasure	**Upstream River Mile**	298.1
Classification	UA: Unconfined anabranching	**Downstream River Mile**	292.3
General Location	From Bighorn confluence	**Length**	5.80 mi (9.33 km)

General Comments From Bighorn confluence: Includes 1 mile of left bank valley wall control; Extensive bank prot.

Narrative Summary

Reach C1 is located just downstream of the Bighorn River confluence. The Reach is 5.8 miles long and is an Unconfined Anabranching reach type, (UA), indicating the presence of forested islands with minimal valley wall influence on the river. These reach types tend to be the most dynamic of all reach types, with typically high rates of bank migration. At RM 296.5 for example, the river has migrated over 250 feet to the southeast between 2001 and 2011, indicating an average migration rate of over 25 feet per year.

There are about 2,300 feet of rock riprap in the reach, which collectively armors about 4 percent of the total bankline. About 1,000 feet of armor is protecting the rail line and another 500 feet is protecting agricultural ground. The remainder is protecting the Rancher's Ditch Diversion Structure at RM 295.5.

The Rancher's Ditch diversion dam is located approximately 2.5 miles downstream of the Bighorn River confluence. The dam was constructed in the early part of the 20th century and feeds a canal that flows on the north side of the river. There is a large, vegetated island in the Yellowstone River at the point of diversion, and diversion dams block channels on both sides of the island. The 2011 imagery shows that the south channel is becoming progressively abandoned, so that most flow goes over the main diversion structure on the north channel.

Since 1950, there have been over 7,000 feet of side channel blocked by floodplain dikes in the reach. These channels are on the lower end of the reach on the left (northwest) bank at RM 293. Even though side channels have been blocked, there has been a net gain of side channel length in the reach; since 1950, the total anabranching channel length has increased by 3,800 feet.

Since 1950, Reach C1 has experienced over 300 acres of new riparian recruitment, with most of that colonization occurring in old 1950s channel area. In balancing the amount of riparian area eroded out to the colonization acreage, there has still been a net gain of 118 acres of riparian area associated with channel movement. This reflects erosion of non-wooded lands and colonization of resulting open bar surfaces by woody vegetation, as well as the fact that the channel has gotten smaller since 1950; the bankfull area dropped by almost 50 acres (6 percent) between 1950 and 2001.

Whereas 8 percent of the 100-year floodplain has become isolated due to human development, about 47 percent (633 acres) of the 5-year floodplain is no longer inundated at that frequency. About 80 acres of historic 100-year floodplain area has become isolated by the railroad, and another 42 acres due to flow alterations. The loss of 5-year floodplain shows the strong imprint of flow alterations below the mouth of the Bighorn River and of development of those areas that are less frequently inundated; about 216 acres of currently flood irrigated floodplain areas are in the historic 5-year floodplain footprint.

Land use is dominated by agriculture, with 1,212 acres of pivot irrigation development since 1950. About 15 of those acres of pivot are within the Channel Migration Zone (CMZ). Approximately 7 percent of the Channel Migration Zone (CMZ) has been restricted, with about half of the restrictions due to riprap along the railroad, and the other half due to floodplain dikes protecting irrigated lands.

There are several corrals associated with an animal handling facility at RM 296.8R. The river is migrating in the direction of these corrals and is currently about 600 feet from the facility.

Reach C1 supports over 40 acres per valley mile of mapped wetland, which is a relatively high wetland density for the river. There are also over 100 acres of Russian olive mapped in the reach, occupying 2.6 percent of the total floodplain area.

Reach C1 has seen a substantial loss in forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 48 acres per valley mile of such forest, and that number decreased to 20 acres per valley mile by 2001.

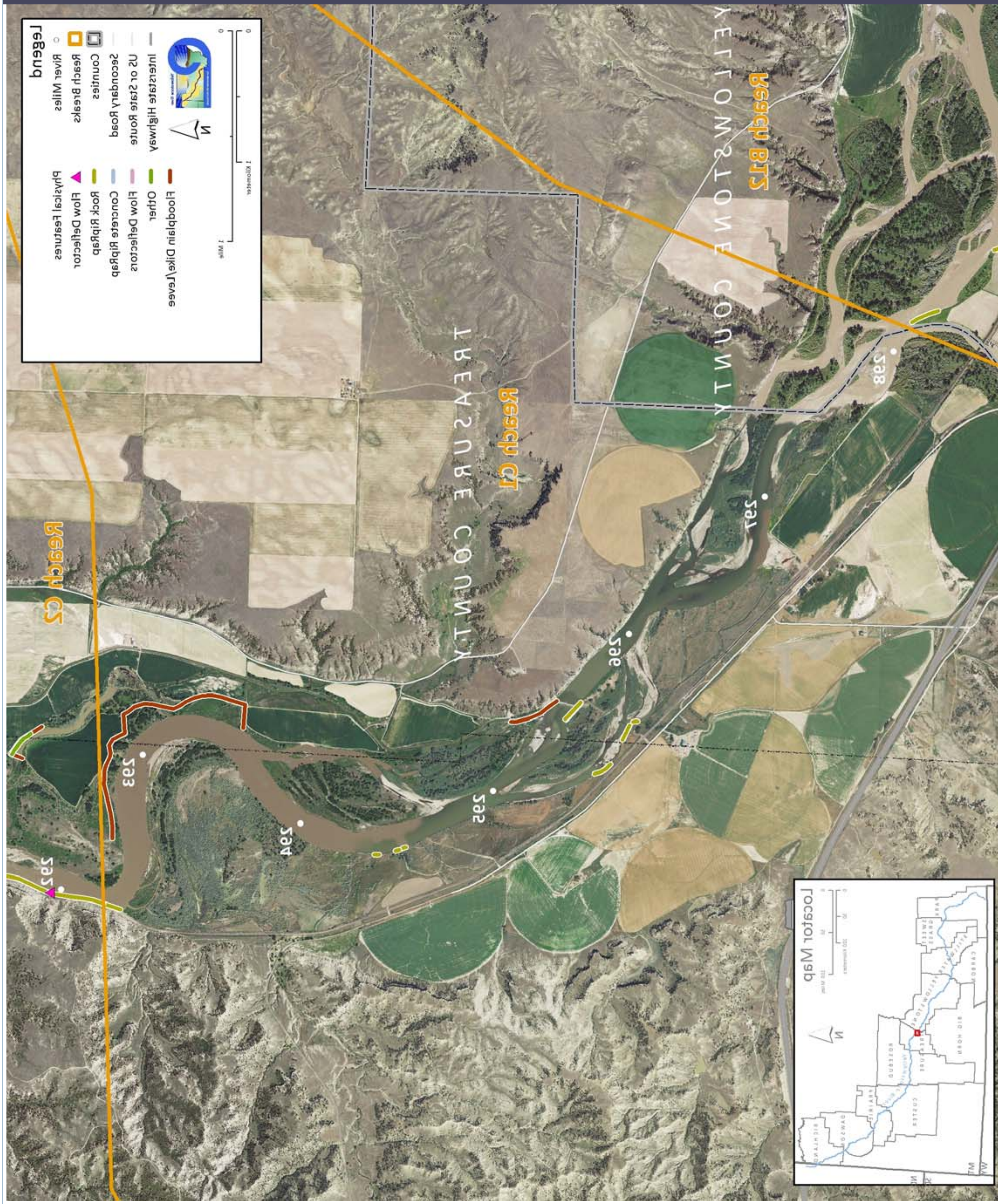
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 60,800 cfs to 47,100 cfs, a drop of about 23 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 20 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,600 cfs to 2,950 cfs with human development, a reduction of 36 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,150 cfs under unregulated conditions to 3,320 cfs under regulated conditions at Reach C10 downstream where the analysis begins, a reduction of 46 percent.

CEA-Related observations in Reach C1 include:
•Blocking of over a mile of side channel by floodplain dikes

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C1 include:
•Fish Passage at Ranchers Ditch Diversion: Structures block two channels at the diversion.
•Watercraft Passage at Ranchers Ditch Diversion
•Irrigation Infrastructure Management at Ranchers Ditch Diversion
•Side channel reactivation at RM 293

- Nutrient management at corrals associated with animal handling facility at RM 296.8R
- Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	108.3	66.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		60,800	76,600	86,900	110,000	119,000	142,000	4,600	3,846
Regulated		47,100	61,400	70,700	91,200	99,900	121,000	2,950	2,227
% Change		-22.53%	-19.84%	-18.64%	-17.09%	-16.05%	-14.79%	-35.87%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	8-Aug-96	B/W		6295000	9110
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/13/2005	color	1-meter pixels	6309000	17700
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	6/29/2009	Color	1-meter pixels	6309000	42200
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/20/2011	Color	1-meter pixels	6309000	46100
2013	NAIP	07/21/2013	color	1-meter pixels	6309000	
2013	NAIP	07/20/2013	color	1-meter pixels	6309000	
2013	NAIP	06/15/2013	color	1-meter pixels	6309000	
2013	NAIP	06/16/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	1,900	3.0%	2,306	3.7%	406
	Feature Type Totals	**1,900**	**3.0%**	**2,306**	**3.7%**	**406**
Floodplain Control						
	Floodplain Dike/Levee	9,038	14.4%	9,038	14.4%	0
	Feature Type Totals	**9,038**	**14.4%**	**9,038**	**14.4%**	**0**
	Reach Totals	**10,938**	**17.5%**	**11,344**	**18.1%**	**406**

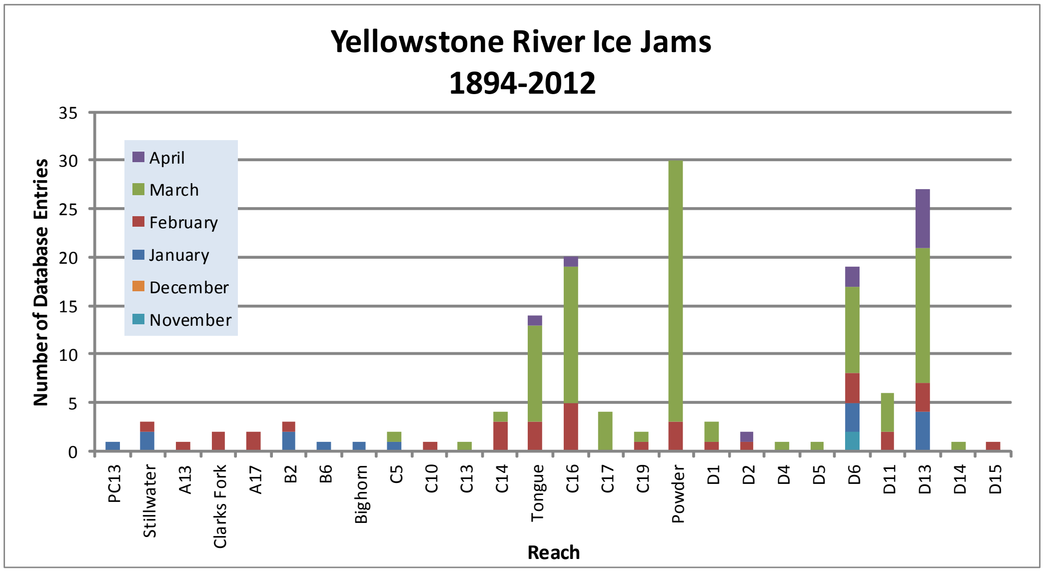
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	0	0	984	0	0	472	0	0
Totals	**0**	**0**	**984**	**0**	**0**	**472**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	31,562	43,000	2.36	1950 to 1976:	8.77%
1976	30,782	48,316	2.57	1976 to 1995:	-6.93%
1995	31,314	43,579	2.39	1995 to 2001:	4.32%
2001	31,294	46,785	2.50	1950 to 2001:	5.62%
Change 1950 - 2001	**-269**	**3,785**	**0.13**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	7,171

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	42	2.2%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	30	1.6%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	80	4.2%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1737		1476	
Total Floodplain Area (Ac)	1889		2110	
Total Isolated (Ac)	**152**	**8.1%**	**633**	**45.9%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	69	0	0	**69**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
355	711	1,804	113	6%	162	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Railroad	56	2.9%
Dike/Levee			
	Irrigated	57	2.9%
	Totals	**113**	**5.7%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
150.0	0.0	14.5	0.0	10.1

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	51	66	54	40	0.9%	1.1%	0.9%	0.7%
	Totals	**51**	**66**	**54**	**40**	**0.9%**	**1.1%**	**0.9%**	**0.7%**
Agricultural Land									
	Non-Irrigated	2,850	2,846	2,739	2,486	48.0%	47.9%	46.1%	41.8%
	Irrigated	1,895	1,816	1,975	2,176	31.9%	30.6%	33.2%	36.6%
	Totals	**4,745**	**4,662**	**4,714**	**4,662**	**79.8%**	**78.4%**	**79.3%**	**78.4%**
Channel									
	Channel	1,062	1,092	1,021	1,082	17.9%	18.4%	17.2%	18.2%
	Totals	**1,062**	**1,092**	**1,021**	**1,082**	**17.9%**	**18.4%**	**17.2%**	**18.2%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	5	0.0%	0.0%	0.0%	0.1%
	Totals	**0**	**0**	**0**	**5**	**0.0%**	**0.0%**	**0.0%**	**0.1%**
Transportation									
	Public Road	54	91	58	58	0.9%	1.5%	1.0%	1.0%
	Interstate	0	0	65	65	0.0%	0.0%	1.1%	1.1%
	Railroad	32	32	32	32	0.5%	0.5%	0.5%	0.5%
	Totals	**85**	**123**	**154**	**154**	**1.4%**	**2.1%**	**2.6%**	**2.6%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	137	177	1,212	0.0%	2.9%	3.7%	26.0%	2.9%	0.8%	22.3%	26.0%
	Flood	1,895	1,679	1,798	964	39.9%	36.0%	38.1%	20.7%	-3.9%	2.1%	-17.5%	-19.3%
	Totals	**1,895**	**1,816**	**1,975**	**2,176**	**39.9%**	**39.0%**	**41.9%**	**46.7%**	**-1.0%**	**2.9%**	**4.8%**	**6.7%**

Non-Irrigated

Multi-Use	2,758	2,449	2,400	2,138	58.1%	52.5%	50.9%	45.9%	-5.6%	-1.6%	-5.0%	-12.3%
Hay/Pasture	92	397	339	348	1.9%	8.5%	7.2%	7.5%	6.6%	-1.3%	0.3%	5.5%
Totals	**2,850**	**2,846**	**2,739**	**2,486**	**60.1%**	**61.0%**	**58.1%**	**53.3%**	**1.0%**	**-2.9%**	**-4.8%**	**-6.7%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.5	0.5	1.1	1.4	0.8	1.2	1.6	1.9	5.4
Max	33.2	155.4	177.4	229.3	28.0	77.6	137.1	47.9	47.1
Average	8.5	17.1	19.1	24.7	11.1	16.2	21.0	23.9	24.3
Sum	169.9	411.4	477.9	468.6	177.1	355.7	188.7	287.1	121.5

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	130.1
Channel to Riparian (acres)	248.3
Riparian Encroachment (acres)	**118.2**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	218.2
1950s Floodplain Mapped as 2011 Channel (Ac)	92.3
Total Recruitment (1950s to 2011)(Ac)	**310.6**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	2.4	121.5	73.2	0.0	**197.1**
Acres/Valley Mile	0.5	25.8	15.5	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	104.53	2.59%	1.31	2.05	9.26	4.44

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	**Bankfull**	**Low Flow**	**% of Low Flow**
Scour Pool	304.8	179.4	17.6%
Rip Rap Margin	3.2	3.1	0.3%
Bluff Pool	46.4	45.5	4.5%
Secondary Channel	64.2	52.4	5.1%
Secondary Channel (Seasonal)	165.7	112.4	11.0%
Channel Crossover	133.1	100.8	9.9%
Point Bar		83.0	8.1%
Side Bar		45.6	4.5%
Mid-channel Bar		23.7	2.3%
Island	292.2	295.5	28.9%
Dry Channel		79.4	7.8%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Treasure	**Upstream River Mile**	292.3
Classification	PCB: Partially confined braided	**Downstream River Mile**	286.8
General Location	To Myers Bridge	**Length**	5.50 mi (8.85 km)
General Comments	To Myers Br (RM 285.5); Railroad adjacent to channel on valley wall; low sinuosity		

Narrative Summary

Reach C2 is located just upstream of Myers Bridge. The Reach is 5.5 miles long and is a Partially Confined Braided (PCB) reach type indicating some valley wall influence on a channel with fairly extensive low flow channels and open gravel bars. The reach follows the southern bluff line along the entire reach, which is almost entirely armored to protect the railroad.

There are over five miles of bank armor in the reach, most of which is rock riprap protecting the rail line. A total of 46 percent of the bank is armored. Since 2001, 1,200 feet of flow deflectors have been built on the right bank just above Myers Bridge.

About two miles of side channel have recently been blocked in Reach C2. In the upper end of the reach, two large side channels were blocked by a several thousand foot long floodplain dike sometime after 1976, and the old island in between these side channels is now cleared and farmed. The heads of these channels are at RM 293, and removal of the plugs at their heads could potentially reactivate over a mile of side channel connectivity. A second channel on the north side of the river at RM 289 appears relatively old, but has access roads crossing it that appear to block seasonal access. Similar to upstream, the isolation of this ~9,000 foot-long side channel has prompted clearing and farming of the old island area that is currently accessible. In total, about 18 percent (162 acres) of the mapped 1950s riparian vegetation in the reach has been cleared and converted to irrigation.

Land use is dominated by agriculture, with 137 acres of pivot irrigation development since 1950. There are several corrals associated with an animal handling facility at RM 289.5L. The corrals are on the edge of a blocked historic side channel that drains to the river. Dikes, levees, and irrigation-related riprap have collectively isolated just over 10 percent of the Channel Migration Zone in Reach C2.

Over 600 acres of 100-year floodplain has been isolated by human development, and all of that isolation is due to agricultural development on the north side of the river. The isolation reflects 23 percent of the total 100-year floodplain. The 5-year floodplain is even more affected; 59 percent of the historic 5-year floodplain is no longer inundated at that frequency. The loss of 5-year floodplain shows the strong imprint of flow alterations below the mouth of the Bighorn River and consequent development of those areas that are less frequently inundated; about 550 acres of currently flood irrigated areas are in the historic 5-year floodplain footprint.

Since 1950, Reach C2 has experienced about 190 acres of new riparian recruitment, with most of that colonization occurring in old 1950s channel area. There has been a net gain of 40 acres of riparian area in the reach associated with channel movement. This reflects encroachment of vegetation into the channel that has experienced a 20 percent reduction in channel forming (2-year) flow. There are about 46 acres of Russian olive in the reach.

Reach C2 was sampled as part of the fisheries study. A total of 32 fish species were sampled in the reach and one of those species was Sauger, which has been identified by the Montana Natural Heritage Program as a Species of Concern (SOC).

Reach C2 has seen a substantial loss in forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 37 acres per valley mile of such forest, and that number decreased to 6 acres per valley mile by 2001.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 60,900 cfs to 47,100 cfs, a drop of about 23 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 20 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,610 cfs to 2,950 cfs with human development, a reduction of 36 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,150 cfs under unregulated conditions to 3,320 cfs under regulated conditions at Reach C10 downstream where the analysis begins, a reduction of 46 percent.

CEA-Related observations in Reach C2 include:
•Blocking of over a mile of side channel by floodplain dikes
•Riparian clearing and irrigation development in isolated 5-year floodplain
•Loss of area at low risk of cowbird parasitism with riparian clearing

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C2 include:
•Side channel reactivation at RM 293
•Side channel reactivation at RM 289
•Nutrient management at corrals associated with an animal handling facility at RM 288.8L
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	102.8	72.1

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		60,900	76,600	87,000	110,000	119,000	142,000	4,610	3,846
Regulated		47,100	61,300	70,700	91,200	100,000	121,000	2,950	2,227
% Change		-22.66%	-19.97%	-18.74%	-17.09%	-15.97%	-14.79%	-36.01%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	8-Aug-96	B/W		6295000	9110
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/13/2005	color	1-meter pixels	6309000	17700
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/30/2009	Color	1-meter pixels	6309000	13800
2009	NAIP	6/29/2009	Color	1-meter pixels	6309000	42200
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/20/2011	Color	1-meter pixels	6309000	46100
2013	NAIP	07/21/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Tree Revetments	702	1.2%	702	1.2%	0
	Rock RipRap	25,527	43.8%	25,537	43.9%	10
	Flow Deflectors	0	0.0%	387	0.7%	387
	Between Flow Deflectors	0	0.0%	869	1.5%	869
	Feature Type Totals	**26,229**	**45.0%**	**27,495**	**47.2%**	**1,266**
Floodplain Control						
	Floodplain Dike/Levee	1,508	2.6%	1,508	2.6%	0
	Feature Type Totals	**1,508**	**2.6%**	**1,508**	**2.6%**	**0**
	Reach Totals	**27,737**	**47.6%**	**29,003**	**49.8%**	**1,266**

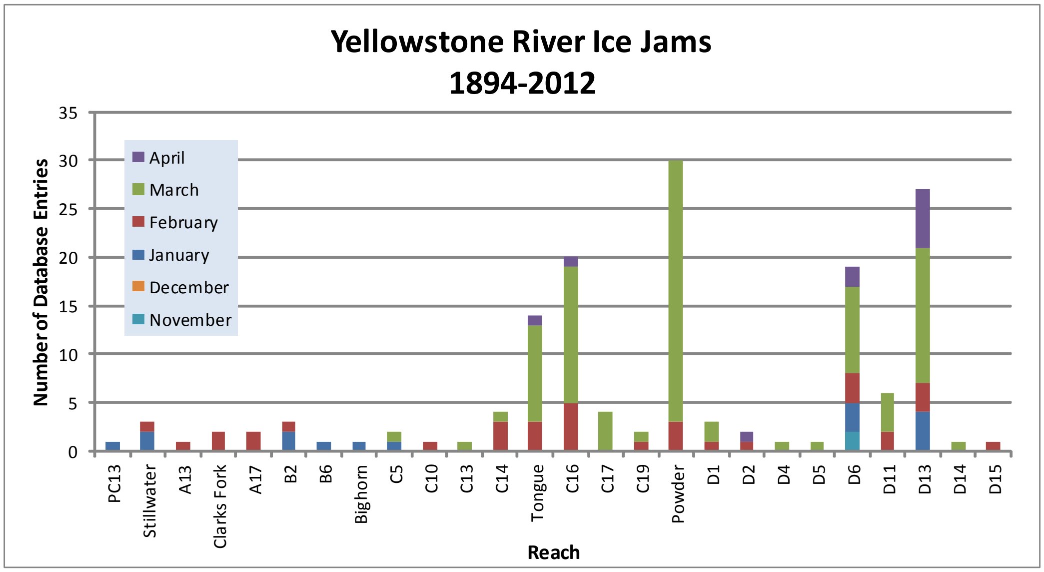
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	1,168	0	0	0	0	24,708	0	0
Tree Revetments	0	0	0	0	0	0	0	0
Totals	**1,168**	**0**	**0**	**0**	**0**	**24,708**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	29,638	28,656	1.97	1950 to 1976:	7.47%
1976	29,979	33,391	2.11	1976 to 1995:	-36.35%
1995	29,256	10,104	1.35	1995 to 2001:	-1.76%
2001	29,112	9,366	1.32	1950 to 2001:	-32.80%
Change 1950 - 2001	**-526**	**-19,291**	**-0.65**		

Length of Side Channels Blocked

Pre-1950s (ft)	1,014
Post-1950s (ft)	10,614

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	129	4.7%		
Agriculture (isloated by canal or large ditch)	476	17.3%		
Levee/Riprap (protecting agricultural lands)	19	0.7%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	2123		1250	
Total Floodplain Area (Ac)	2747		2209	
Total Isolated (Ac)	**624**	**22.7%**	**959**	**59.3%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	217	0	0	**217**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
331	663	1,517	143	9%	126	15	12%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Irrigated	47	2.8%
Flow Deflectors			
	Non-Irrigated	10	0.6%
Dike/Levee			
	Public Road	2	0.1%
	Irrigated	109	6.6%
	Totals	**168**	**10.2%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
244.3	0.0	0.0	0.0	0.1

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	69	170	187	190	1.1%	2.7%	3.0%	3.0%
	Totals	**69**	**170**	**187**	**190**	**1.1%**	**2.7%**	**3.0%**	**3.0%**
Agricultural Land									
	Non-Irrigated	2,677	2,590	2,755	2,700	42.3%	41.0%	43.6%	42.7%
	Irrigated	2,465	2,434	2,566	2,610	39.0%	38.5%	40.6%	41.3%
	Totals	**5,141**	**5,024**	**5,321**	**5,311**	**81.3%**	**79.5%**	**84.1%**	**84.0%**
Channel									
	Channel	1,057	1,076	758	765	16.7%	17.0%	12.0%	12.1%
	Totals	**1,057**	**1,076**	**758**	**765**	**16.7%**	**17.0%**	**12.0%**	**12.1%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	5	5	0.0%	0.0%	0.1%	0.1%
	Totals	**0**	**0**	**5**	**5**	**0.0%**	**0.0%**	**0.1%**	**0.1%**
Transportation									
	Public Road	24	21	21	21	0.4%	0.3%	0.3%	0.3%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	33	33	33	33	0.5%	0.5%	0.5%	0.5%
	Totals	**57**	**54**	**54**	**54**	**0.9%**	**0.8%**	**0.8%**	**0.8%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	77	79	0.0%	0.0%	1.4%	1.5%	0.0%	1.4%	0.0%	1.5%
	Pivot	0	0	138	138	0.0%	0.0%	2.6%	2.6%	0.0%	2.6%	0.0%	2.6%
	Flood	2,465	2,434	2,351	2,394	47.9%	48.4%	44.2%	45.1%	0.5%	-4.3%	0.9%	-2.9%
	Totals	**2,465**	**2,434**	**2,566**	**2,610**	**47.9%**	**48.4%**	**48.2%**	**49.2%**	**0.5%**	**-0.2%**	**0.9%**	**1.2%**

Non-Irrigated													
	Multi-Use	2,601	2,510	2,736	2,697	50.6%	49.9%	51.4%	50.8%	-0.6%	1.5%	-0.6%	0.2%
	Hay/Pasture	76	81	19	3	1.5%	1.6%	0.4%	0.1%	0.1%	-1.3%	-0.3%	-1.4%
	Totals	**2,677**	**2,590**	**2,755**	**2,700**	**52.1%**	**51.6%**	**51.8%**	**50.8%**	**-0.5%**	**0.2%**	**-0.9%**	**-1.2%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.9	0.3	1.4	0.1	0.0	2.0	4.7	0.3	1.8
Max	28.3	27.0	86.8	78.9	156.8	107.5	167.0	96.0	126.0
Average	9.6	8.2	16.1	19.8	37.8	31.2	59.9	22.7	29.9
Sum	172.2	180.1	241.1	276.7	416.0	374.0	479.1	182.0	149.7

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	90.0
Channel to Riparian (acres)	128.7
Riparian Encroachment (acres)	**38.8**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	136.8
1950s Floodplain Mapped as 2011 Channel (Ac)	56.3
Total Recruitment (1950s to 2011)(Ac)	**193.1**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	2.3	68.1	33.6	0.0	**104.1**
Acres/Valley Mile	0.4	12.7	6.3	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	45.84	0.87%	1.02	4.89	7.04	6.59

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
	✓	Bigmouth buffalo
✓	✓	Black bullhead
✓	✓	Black crappie
	✓	Blue sucker
✓	✓	Bluegill
✓	✓	Brook stickleback
✓	✓	Brown trout
✓	✓	Burbot
		Catfish species
✓	✓	Channel catfish
✓	✓	Common carp
✓	✓	Creek chub
✓	✓	Emerald shiner
✓	✓	Fathead minnow
✓	✓	Flathead chub
✓	✓	Freshwater drum
✓	✓	Goldeye
✓	✓	Green sunfish
	✓	Lake chub
✓	✓	Largemouth bass
✓	✓	Longnose dace
✓	✓	Longnose sucker
✓	✓	Minnow species
		Mottled sculpin
✓	✓	Mountain sucker
	✓	Mountain whitefish
	✓	Northern pike
	✓	Northern plains killifish
		Northern redbelly dace
		Pallid sturgeon
✓	✓	Pumpkinseed
		Rainbow trout
✓	✓	River carpsucker
	✓	Rock bass
✓	✓	Sand shiner
✓	✓	Sauger
✓	✓	Shorthead redhorse
		Shortnose gar
	✓	Shovelnose sturgeon
		Sicklefin chub
✓	✓	Smallmouth bass
✓	✓	Smallmouth buffalo
✓	✓	Stonecat
		Sturgeon chub
✓	✓	Sucker species
	✓	Sunfish species
✓	✓	Walleye
✓	✓	Western silvery minnow
		White bass
	✓	White crappie
✓	✓	White sucker
	✓	Yellow bullhead
		Yellow perch

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	100.3	50.4	6.6%
Rip Rap Bottom		3.1	0.4%
Rip Rap Margin	166.6	127.3	16.8%
Secondary Channel	78.8	71.6	9.4%
Secondary Channel (Seasonal)	111.0	52.4	6.9%
Channel Crossover	133.3	103.8	13.7%
Point Bar		6.4	0.8%
Side Bar		29.0	3.8%
Mid-channel Bar		97.1	12.8%
Island	167.6	167.6	22.1%
Dry Channel		49.0	6.5%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Treasure	**Upstream River Mile**	286.8
Classification	UA: Unconfined anabranching	**Downstream River Mile**	282
General Location	To Yellowstone Diversion	**Length**	4.80 mi (7.72 km)

General Comments Just downstream of Myers Bridge, Reach C3 provides an example of the extent of Channel Migration Zone isolation that can occur in the vicinity of transportation and irrigation infrastructure.

Narrative Summary

Reach C3 is located in Treasure County, between Myers Bridge and the Yellowstone Ditch Diversion, at the head of the Mission Valley. The reach is a 4.4 mile long Unconfined Anabranching reach type, extending from RM 282.0 to RM 286.4. In this area the alluvial valley bottom is approximately 2.5 miles wide, and this broad valley configuration is due to the presence of relatively erodible Cretaceous-age Bearpaw Shale in the valley walls and valley floor on the west limb of the Porcupine Dome. The Bearpaw Shale consists of dark gray shale that is approximately 800 feet thick. The unit is commonly exposed in the valley walls where the Yellowstone valley bottom is anomalously wide, such as in the Mission and Hammond Valleys, indicating that it is erodible in comparison to the resistant sandstones that typically form the valley margin. Upstream of Myers Bridge, the river has undercut its right bank where Bearpaw Shale underlies Hell Creek sandstone. The rail line follows the river's edge on the sandstone, and land sliding on the shale horizon has resulted in extensive bank armoring to protect the rail line (Womack, 2001).

This reach was used by Koch (1977) to exemplify an especially dynamic river segment where the channel crosses the valley from one valley wall to another. Koch (1977) and Womack (2001) noted that in these areas, the Yellowstone River exhibits a particularly rich and diverse riparian zone.

There are over two miles of bank armor in the reach, all of which is rock riprap. A total of 25 percent of the bank is armored. In addition, approximately 31,000 linear feet of transportation encroachments and floodplain dikes were mapped in the reach. These floodplain features include floodplain dikes at Myers Bridge and the Yellowstone Ditch Diversion, and a long segment of railroad grade that is on a high terrace margin adjacent to an anabranching channel thread. Several of the floodplain dikes are protected by riprap. Land use is dominated by agriculture, with 33 acres of pivot irrigation development since 1950. Physical features such as bank armor, dikes, and levees have isolated 19 percent of the Channel Migration Zone in Reach C3.

The Yellowstone Ditch Diversion Dam is located at the lower end of Reach C3 at River Mile 282. The structure was built in 1909.

Even though Reach C3 has extensive armoring and diking throughout the reach, it has maintained substantial side channel connectivity.

Over 300 acres of 100-year floodplain has been isolated by human development, and all of that isolation is due to agricultural development on the north side of the river. The isolation reflects 12 percent of the total 100-year floodplain. The 5-year floodplain is even more affected; 65 percent of the historic 5-year floodplain is no longer inundated at that frequency. The loss of 5-year floodplain shows the strong imprint of flow alterations below the mouth of the Bighorn River and consequent development of those areas that are less frequently inundated; about 700 acres of currently irrigated areas are in the historic 5-year floodplain footprint.

Reach C3 shows a net encroachment of 192 acres of woody vegetation into the active channel corridor, suggesting that hydrologic alterations may have driven some channel narrowing since 1950. This is also supported by the loss of 121 acres of bankfull area between 1950 and 2001. This reflects encroachment of vegetation into the channel that has experienced a 20 percent reduction in channel forming (2-year) flow. There are about 21 acres of Russian olive in the reach. The reach supports about 30 acres of wetland per valley mile, which is a relatively dense wetland concentration for the corridor.

Reach C3 was sampled as part of the fisheries study. A total of 32 fish species were sampled in the reach and one of those species was Sauger, which has been identified by the Montana Natural Heritage Program as a Species of Concern (SOC).

Reach C3 was sampled as part of the avian study. A total of 39 bird species were identified in the reach. The average species richness in Reach C3 was 8.1, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. Three bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were also found, the Chimney Swift, the Ovenbird and the Plumbeous Vireo. One species identified as a Species of Concern (SOC) was documented, the Read-headed Woodpecker. In contrast to most other reaches, Reach C3 has seen an increase in the forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 65 acres per valley mile of such forest, and that number increased to 82 acres per valley mile by 2001.

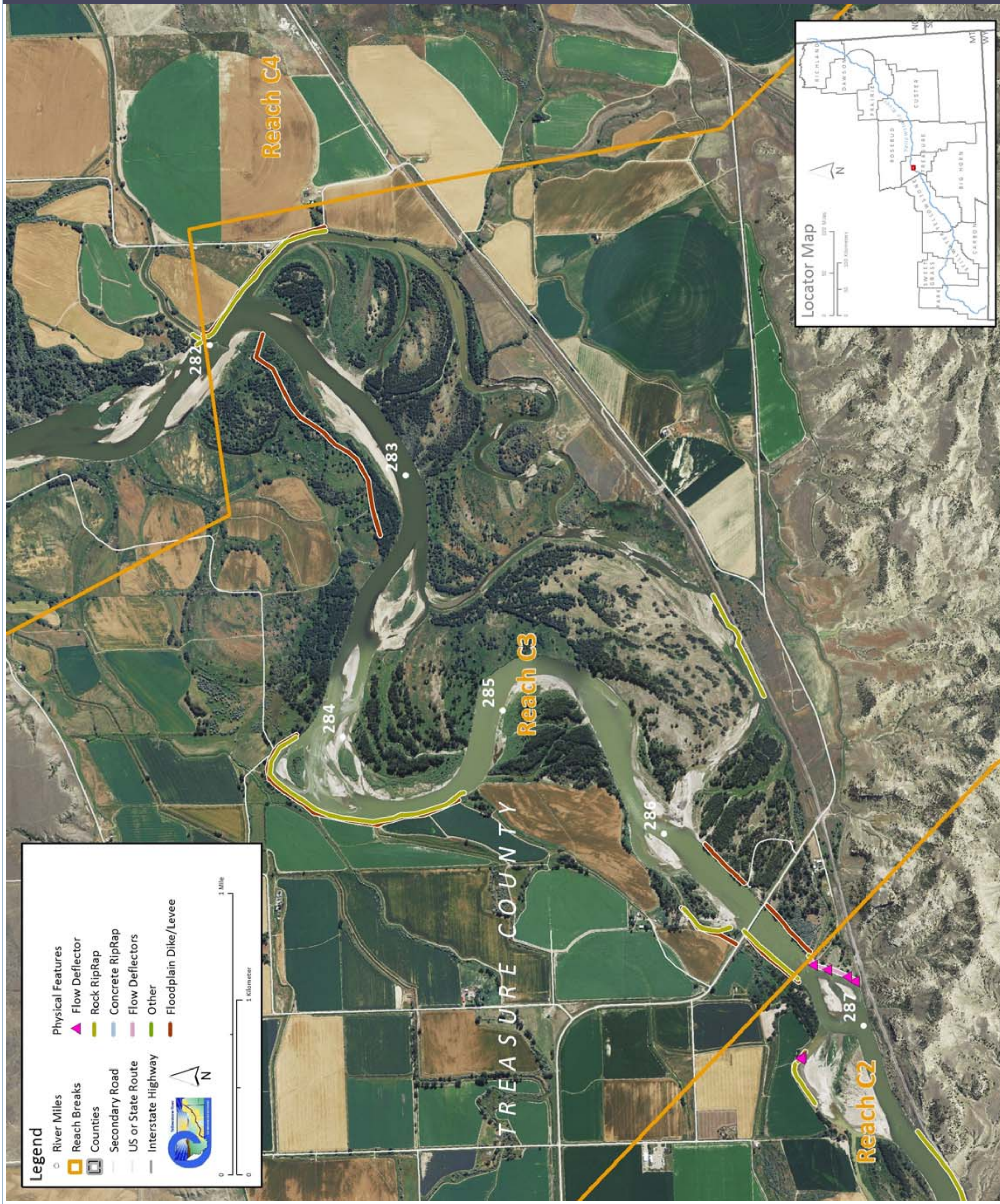
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 23 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,610 cfs to 2,950 cfs with human development, a reduction of 36 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,150 cfs under unregulated conditions to 3,320 cfs under regulated conditions at Reach C10 downstream where the analysis begins, a reduction of 46 percent.

CEA-Related observations in Reach C3 include:
•Influence of flow alterations on floodplain inundation and riparian extent
•Increase in area at low risk of cowbird parasitism with riparian encroachment

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C3 include:

- Fish passage at Yellowstone Ditch Diversion RM 282
- Watercraft passage at Yellowstone Ditch Diversion at RM 282
- Irrigation diversion infrastructure management at Yellowstone Ditch Diversion at RM 282
- Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	98.0	77.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		60,900	76,600	87,000	110,000	119,000	142,000	4,610	3,846
Regulated		47,100	61,300	70,700	91,200	100,000	121,000	2,950	2,227
% Change		-22.66%	-19.97%	-18.74%	-17.09%	-15.97%	-14.79%	-36.01%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	8/8/96 - 7/14/96	B/W		6295000	25300
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/13/2005	color	1-meter pixels	6309000	17700
2007	Woolpert	10/15/2007 - 11/2/0007	Color		6309000	6490
2009	NAIP	7/30/2009	Color	1-meter pixels	6309000	13800
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/20/2011	Color	1-meter pixels	6309000	46100
2013	NAIP	07/13/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	12,557	25.2%	12,618	25.4%	62
	Feature Type Totals	**12,557**	**25.2%**	**12,618**	**25.4%**	**62**
Floodplain Control						
	Transportation Encroachment	13,219	26.6%	13,219	26.6%	0
	Floodplain Dike/Levee	17,438	35.1%	17,438	35.1%	0
	Feature Type Totals	**30,657**	**61.6%**	**30,657**	**61.6%**	**0**
	Reach Totals	**43,214**	**86.9%**	**43,276**	**87.0%**	**62**

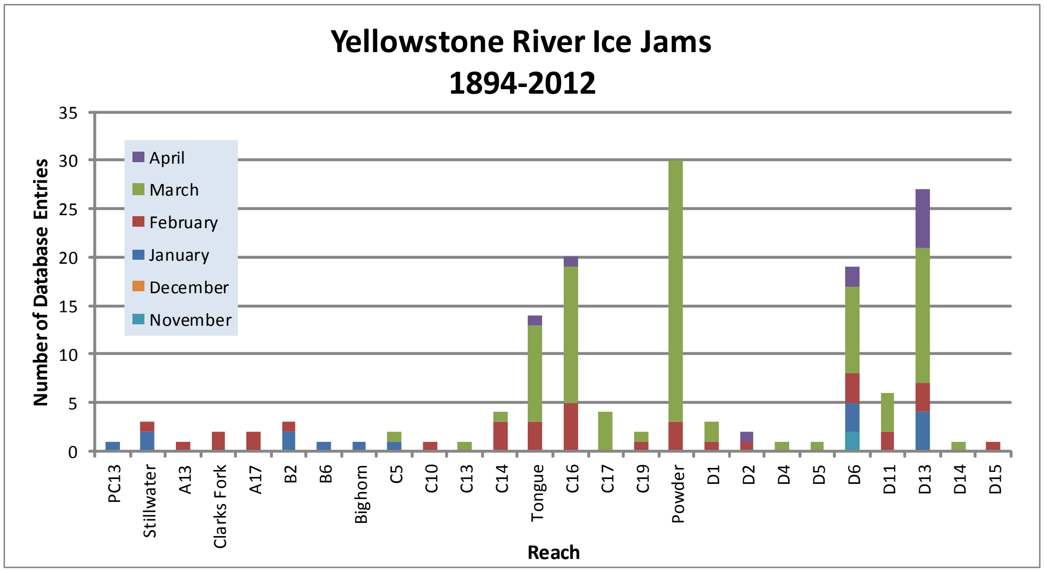
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	7,856	0	492	2,165	0	2,158	0	0
Totals	**7,856**	**0**	**492**	**2,165**	**0**	**2,158**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	27,296	37,678	2.38	1950 to 1976:	-2.87%
1976	29,355	38,514	2.31	1976 to 1995:	16.55%
1995	24,717	41,887	2.69	1995 to 2001:	-2.69%
2001	24,872	40,347	2.62	1950 to 2001:	10.16%
Change 1950 - 2001	**-2,424**	**2,669**	**0.24**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	45	1.6%		
Levee/Riprap (protecting agricultural lands)	188	6.9%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	81	3.0%		
Total Not Isolated (Ac)	2409		1245	
Total Floodplain Area (Ac)	2723		2442	
Total Isolated (Ac)	**314**	**11.5%**	**1197**	**65.1%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	113	0	0	**113**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
512	1,024	2,249	476	21%	283	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Railroad	27	1.1%
	Public Road	69	2.7%
	Irrigated	205	8.1%
Flow Deflectors			
	Non-Irrigated	0	0.0%
Dike/Levee			
	Public Road	69	2.7%
	Non-Irrigated	106	4.2%
	Totals	**476**	**18.8%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
393.6	0.0	17.9	1.4	9.2

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	8	8	8	8	0.2%	0.2%	0.2%	0.2%
	Agricultural Roads	0	11	11	11	0.0%	0.2%	0.2%	0.2%
	Other Infrastructure	33	74	89	89	0.7%	1.6%	1.9%	1.9%
	Totals	**41**	**93**	**108**	**108**	**0.9%**	**2.0%**	**2.3%**	**2.3%**
Agricultural Land									
	Non-Irrigated	1,394	1,406	1,409	1,367	29.2%	29.5%	29.6%	28.7%
	Irrigated	1,882	1,817	1,821	1,811	39.5%	38.1%	38.2%	38.0%
	Totals	**3,276**	**3,223**	**3,229**	**3,177**	**68.7%**	**67.6%**	**67.8%**	**66.7%**
Channel									
	Channel	1,410	1,402	1,381	1,425	29.6%	29.4%	29.0%	29.9%
	Totals	**1,410**	**1,402**	**1,381**	**1,425**	**29.6%**	**29.4%**	**29.0%**	**29.9%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	8	0.0%	0.0%	0.0%	0.2%
	Totals	**0**	**0**	**0**	**8**	**0.0%**	**0.0%**	**0.0%**	**0.2%**
Transportation									
	Public Road	22	31	31	31	0.5%	0.7%	0.6%	0.6%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	17	17	17	17	0.4%	0.4%	0.4%	0.4%
	Totals	**39**	**48**	**48**	**48**	**0.8%**	**1.0%**	**1.0%**	**1.0%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	33	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	1.0%	1.0%
	Flood	1,882	1,817	1,821	1,778	57.4%	56.4%	56.4%	55.9%	-1.1%	0.0%	-0.4%	-1.5%
	Totals	**1,882**	**1,817**	**1,821**	**1,811**	**57.4%**	**56.4%**	**56.4%**	**57.0%**	**-1.1%**	**0.0%**	**0.6%**	**-0.5%**

Non-Irrigated													
	Multi-Use	1,244	1,356	1,378	1,336	38.0%	42.1%	42.7%	42.0%	4.1%	0.6%	-0.6%	4.1%
	Hay/Pasture	150	50	31	31	4.6%	1.5%	1.0%	1.0%	-3.1%	-0.6%	0.0%	-3.6%
	Totals	**1,394**	**1,406**	**1,409**	**1,367**	**42.6%**	**43.6%**	**43.6%**	**43.0%**	**1.1%**	**0.0%**	**-0.6%**	**0.5%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.4	0.4	0.7	0.1	1.5	1.0	10.8	1.6	1.9
Max	47.8	107.1	75.5	272.5	79.0	154.8	63.2	141.9	102.6
Average	7.9	14.6	14.6	32.5	19.3	33.7	25.0	36.8	29.0
Sum	213.3	365.7	320.6	747.4	521.5	674.1	99.8	368.0	347.6

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	122.1
Channel to Riparian (acres)	314.2
Riparian Encroachment (acres)	**192.1**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	318.6
1950s Floodplain Mapped as 2011 Channel (Ac)	79.4
Total Recruitment (1950s to 2011)(Ac)	**398.0**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	6.4	90.6	23.2	0.0	**120.2**
Acres/Valley Mile	2.0	28.7	7.4	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	21.17	0.60%	5.66	4.51	2.15	1.40

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
	✓	Bigmouth buffalo
✓	✓	Black bullhead
	✓	Black crappie
	✓	Blue sucker
	✓	Bluegill
✓	✓	Brook stickleback
✓	✓	Brown trout
✓	✓	Burbot
		Catfish species
✓	✓	Channel catfish
✓	✓	Common carp
✓	✓	Creek chub
✓	✓	Emerald shiner
✓	✓	Fathead minnow
✓	✓	Flathead chub
✓	✓	Freshwater drum
✓	✓	Goldeye
✓	✓	Green sunfish
✓	✓	Lake chub
	✓	Largemouth bass
✓	✓	Longnose dace
✓	✓	Longnose sucker
✓	✓	Minnow species
		Mottled sculpin
✓	✓	Mountain sucker
	✓	Mountain whitefish
	✓	Northern pike
✓	✓	Northern plains killifish
		Northern redbelly dace
		Pallid sturgeon
✓	✓	Pumpkinseed
		Rainbow trout
✓	✓	River carpsucker
	✓	Rock bass
✓	✓	Sand shiner
✓	✓	Sauger
✓	✓	Shorthead redhorse
		Shortnose gar
	✓	Shovelnose sturgeon
		Sicklefin chub
✓	✓	Smallmouth bass
✓	✓	Smallmouth buffalo
✓	✓	Stonecat
		Sturgeon chub
✓	✓	Sucker species
	✓	Sunfish species
✓	✓	Walleye
✓	✓	Western silvery minnow
		White bass
✓	✓	White crappie
✓	✓	White sucker
	✓	Yellow bullhead
		Yellow perch

Low Flow Fisheries Habitat Mapping

2001 (Acres)

Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	123.5	81.6	5.9%
Rip Rap Bottom	69.2	52.3	3.8%
Secondary Channel	21.1	22.0	1.6%
Secondary Channel (Seasonal)	216.1	147.4	10.7%
Channel Crossover	146.7	81.1	5.9%
Point Bar		45.0	3.3%
Side Bar		96.8	7.0%
Mid-channel Bar		30.5	2.2%
Island	777.7	777.7	56.3%
Dry Channel		23.2	1.7%
Dam Influenced	26.5	23.2	1.7%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern

Potential Species of Concern

Reach	Region	Species
✓	✓	American Robin
✓	✓	American Crow
✓	✓	American Goldfinch
	✓	American Kestrel
✓	✓	American Redstart
	✓	Bald Eagle
		Baltimore Oriole
	✓	Barn Swallow
✓	✓	Belted Kingfisher
	✓	Black-billed Cuckoo
	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
	✓	Black-and-white Warbler
✓	✓	Black-headed Grosbeak
	✓	Blue Jay
	✓	Bobolink
	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
✓	✓	Brown Creeper
✓	✓	Brown Thrasher
✓	✓	Bullock's Oriole
✓	✓	Canada Goose
✓	✓	Cedar Waxwing
✓	✓	Chimney Swift
✓	✓	Chipping Sparrow
	✓	Clay-collared Sparrow
✓	✓	Cliff Swallow
✓	✓	Common Grackle
	✓	Common Merganser
	✓	Common Nighthawk
		Common Raven
✓	✓	Common Yellowthroat
	✓	Cooper's Hawk
	✓	Dickcissel
✓	✓	Downy Woodpecker
	✓	Eastern Bluebird
✓	✓	Eastern Kingbird
	✓	Eurasian Collared-dove
✓	✓	European Starling
	✓	Field Sparrow
✓	✓	Franklin's Gull
	✓	Grasshopper Sparrow
✓	✓	Gray Catbird
✓	✓	Great Blue Heron
	✓	Great Horned Owl
✓	✓	Hairy Woodpecker
		House Finch
✓	✓	House Wren
✓	✓	Killdeer
	✓	Lark Bunting
✓	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
	✓	Mallard
		Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
	✓	Orchard Oriole
		Osprey
✓	✓	Ovenbird
✓	✓	Plumbeous Vireo
✓	✓	Red-headed Woodpecker
		Red-naped Sapsucker
	✓	Red Crossbill
✓	✓	Ring-necked Pheasant
✓	✓	Red-tailed hawk
	✓	Rock Dove
✓	✓	Red-winged Blackbird
✓	✓	Red-eyed Vireo
		Red-breasted Grosbeak
	✓	Say's Phoebe
✓	✓	Savannah Sparrow
✓	✓	Song Sparrow
	✓	Spotted Sandpiper
✓	✓	Spotted Towhee
	✓	Sharp-shinned Hawk
✓	✓	Swainson's Thrush
✓	✓	Sandhill Crane
✓	✓	Tree Swallow
✓	✓	Turkey Vulture
	✓	Upland Sandpiper
✓	✓	Vesper Sparrow
✓	✓	Violet-green Swallow
✓	✓	Warbling Vireo
✓	✓	Western Kingbird
✓	✓	Western Meadowlark
✓	✓	Western Wood-pewee
✓	✓	White-breasted Nuthatch
✓	✓	White-throated Swift
✓	✓	Wild Turkey
✓	✓	Wood Duck
		Yellow-bellied Sapsucker
		Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
		Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Treasure	**Upstream River Mile**	282
Classification	PCB: Partially confined braided	**Downstream River Mile**	278.2
General Location	Below Yellowstone Diversion	**Length**	3.80 mi (6.12 km)
General Comments	Below Yellowstone Diversion		

Narrative Summary

Reach C4 is located in Treasure County, below Yellowstone Diversion Dam. Amelia Island Fishing Access Site is located in the middle of the reach. The reach is a 3.8 mile long Partially Confined Braided reach type, indicating some influence of the valley wall along with fairly common mid-channel bars. Within this reach the river trends toward and along the north valley wall near Hysham.

There are almost 5,000 feet of bank armor in the reach, all of which is rock riprap protecting flood irrigated fields at RM 279. Channel migration at the upstream end of this armor will pose risk of flanking as the bankline continues to erode to the south. A total of 13 percent of the bank is armored. Land use is dominated by agriculture, with 371 acres of pivot irrigation development since 1950. Physical features such as bank armor, dikes, and levees have isolated 9 percent of the Channel Migration Zone in Reach C4. All of the armor is protecting agricultural land. There are 22 acres of land in the CMZ under pivot irrigation.

Reach C4 has lost 8,200 feet of side channel length since 1950; however none of those lost channels were mapped as intentionally blocked.

Reach C4 shows a reduction in floodplain turnover rates from 3.4 acres/valley mile/year from 1950-1976 to 1.8 acres/valley mile/year from 1976-2001. There has also been a net loss of 15.5 acres of mid-channel bars since 1950, and a 10 acre increase in bank-attached bars, indicating a loss in overall low flow channel complexity. About 120 acres of riparian area has been cleared for irrigation, which is 18 percent of the total mapped 1950 riparian zone. There are 34 acres of Russian olive in the reach.

Over 300 acres of 100-year floodplain has been isolated by human development, and all of that isolation is due to agricultural development on the south side of the river. The isolation reflects 20 percent of the total 100-year floodplain. The 5-year floodplain is even more affected; 35 percent of the historic 5-year floodplain is no longer inundated at that frequency. The isolation of the historic 5-year floodplain, which is due primarily to flow alterations, has been associated with increased development in these areas; currently there are about 160 acres of flood irrigated land and 40 acres of pivot within the historic 5-year floodplain.

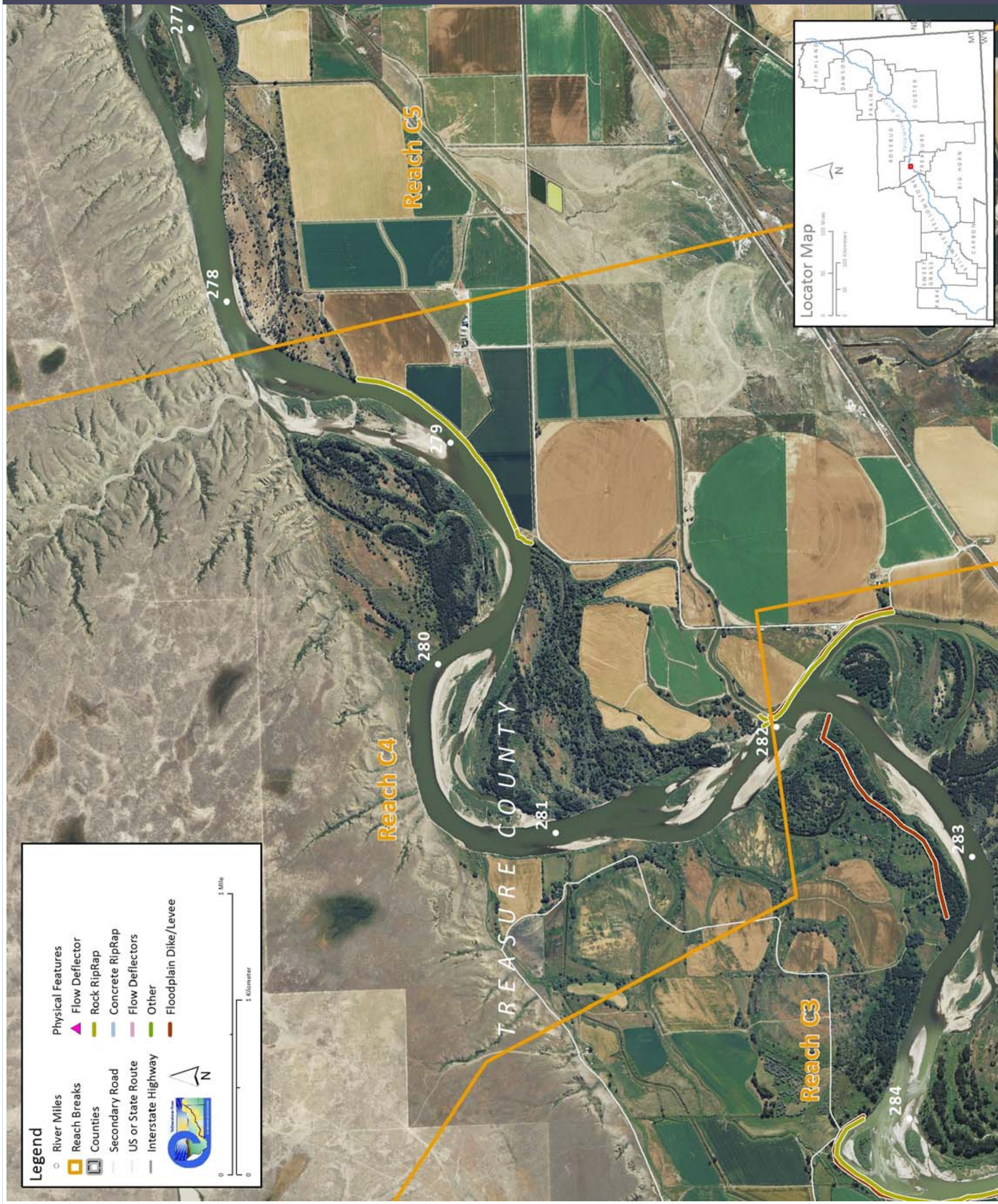
Reach C4 was sampled as part of the avian study. A total of 39 bird species were identified in the reach. Two bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were also found, the Chimney Swift, and the Ovenbird. In contrast to most other reaches, Reach C4 has seen an increase in the forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 43 acres per valley mile of such forest, and that number increased to 138 acres per valley mile by 2001.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 23 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,620 cfs to 2,960 cfs with human development, a reduction of 36 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,150 cfs under unregulated conditions to 3,320 cfs under regulated conditions at Reach C10 downstream where the analysis begins, a reduction of 46 percent.

CEA-Related observations in Reach C4 include:
•Influence of flow alterations on floodplain inundation and riparian extent
•Increase in area at low risk of cowbird parasitism with riparian encroachment

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C4 include:
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	94.2	82.4

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		60,900	76,700	87,000	110,000	120,000	143,000	4,620	3,846
Regulated		47,100	61,300	70,700	91,200	100,000	121,000	2,960	2,227
% Change		-22.66%	-20.08%	-18.74%	-17.09%	-16.67%	-15.38%	-35.93%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	1995?	B/W		6295000	
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/13/2005	color	1-meter pixels	6309000	17700
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/30/2009	Color	1-meter pixels	6309000	13800
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/20/2011	Color	1-meter pixels	6309000	46100
2011	NAIP	7/17/2011	Color	1-meter pixels	6309000	54600
2013	NAIP	07/20/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	4,376	11.0%	4,972	12.5%	595
	Feature Type Totals	**4,376**	**11.0%**	**4,972**	**12.5%**	**595**
	Reach Totals	**4,376**	**11.0%**	**4,972**	**12.5%**	**595**

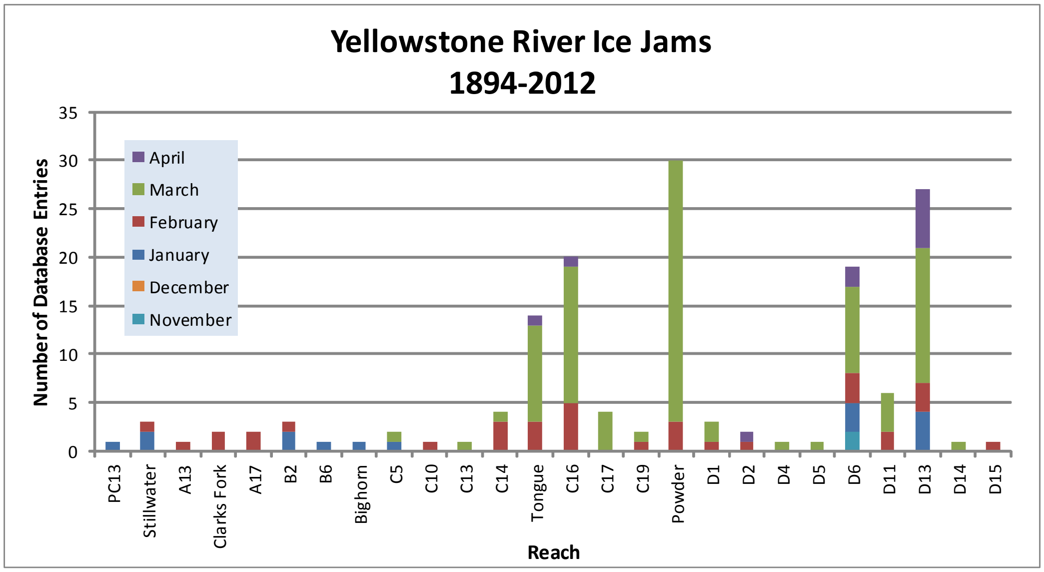
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	4,346	0	0	0	0	0	0	0
Totals	**4,346**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	18,505	14,169	1.77	1950 to 1976:	-28.18%
1976	19,287	5,171	1.27	1976 to 1995:	4.10%
1995	19,319	6,184	1.32	1995 to 2001:	-1.59%
2001	19,946	5,966	1.30	1950 to 2001:	-26.42%
Change 1950 - 2001	**1,441**	**-8,203**	**-0.47**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	101	6.2%		
Levee/Riprap (protecting agricultural lands)	223	13.6%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1317		1076	
Total Floodplain Area (Ac)	1641		1440	
Total Isolated (Ac)	**324**	**19.7%**	**364**	**34.7%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	232	0	1	**232**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
386	772	1,031	114	11%	234	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Irrigated	114	9.0%
	Totals	**114**	**9.0%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
269.9	0.0	22.2	0.0	2.2

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	32	32	32	32	1.0%	1.0%	1.0%	1.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	34	26	5	5	1.1%	0.8%	0.2%	0.2%
	Totals	**66**	**58**	**37**	**37**	**2.0%**	**1.8%**	**1.1%**	**1.1%**
Agricultural Land									
	Non-Irrigated	1,477	1,265	1,567	1,502	45.2%	38.7%	48.0%	46.0%
	Irrigated	1,279	1,437	1,143	1,178	39.2%	44.0%	35.0%	36.1%
	Totals	**2,756**	**2,701**	**2,710**	**2,680**	**84.4%**	**82.8%**	**83.0%**	**82.1%**
Channel									
	Channel	411	474	486	516	12.6%	14.5%	14.9%	15.8%
	Totals	**411**	**474**	**486**	**516**	**12.6%**	**14.5%**	**14.9%**	**15.8%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	22	22	22	22	0.7%	0.7%	0.7%	0.7%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	9	9	9	9	0.3%	0.3%	0.3%	0.3%
	Totals	**31**	**31**	**31**	**31**	**0.9%**	**0.9%**	**0.9%**	**0.9%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	371	0.0%	0.0%	0.0%	13.8%	0.0%	0.0%	13.8%	13.8%
	Flood	1,279	1,437	1,143	808	46.4%	53.2%	42.2%	30.1%	6.8%	-11.0%	-12.0%	-16.3%
	Totals	**1,279**	**1,437**	**1,143**	**1,178**	**46.4%**	**53.2%**	**42.2%**	**44.0%**	**6.8%**	**-11.0%**	**1.8%**	**-2.5%**

Non-Irrigated													
	Multi-Use	1,477	1,265	1,532	1,467	53.6%	46.8%	56.5%	54.7%	-6.8%	9.7%	-1.8%	1.1%
	Hay/Pasture	0	0	35	35	0.0%	0.0%	1.3%	1.3%	0.0%	1.3%	0.0%	1.3%
	Totals	**1,477**	**1,265**	**1,567**	**1,502**	**53.6%**	**46.8%**	**57.8%**	**56.0%**	**-6.8%**	**11.0%**	**-1.8%**	**2.5%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.8	0.0	1.3	1.7	0.7	0.5	15.2	2.8	9.4
Max	24.8	29.8	12.8	342.0	197.7	255.9	26.4	62.6	56.4
Average	9.2	9.8	6.0	90.2	68.1	77.5	20.6	22.7	23.0
Sum	100.8	127.9	71.7	541.4	340.5	387.4	82.3	113.5	91.8

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	63.2
Channel to Riparian (acres)	75.5
Riparian Encroachment (acres)	**12.4**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	76.7
1950s Floodplain Mapped as 2011 Channel (Ac)	8.8
Total Recruitment (1950s to 2011)(Ac)	**85.5**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	1.8	30.7	25.1	0.0	**57.5**
Acres/Valley Mile	0.8	12.9	10.6	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	33.88	1.58%	6.69	0.02	6.62	1.78

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	24.6	7.2	1.5%
Rip Rap Bottom	77.3	54.3	11.2%
Bluff Pool	80.5	53.7	11.0%
Secondary Channel	40.6	33.9	7.0%
Secondary Channel (Seasonal)	46.5	19.7	4.1%
Channel Crossover	121.7	82.0	16.9%
Point Bar		36.2	7.4%
Side Bar		40.4	8.3%
Mid-channel Bar		6.4	1.3%
Island	95.0	95.0	19.5%
Dry Channel		57.4	11.8%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern

Potential Species of Concern

Reach	Region	Species
☑	☑	American Robin
☑	☑	American Crow
☐	☐	American Goldfinch
☐	☑	American Kestrel
☑	☑	American Redstart
☑	☑	Bald Eagle
☐	☐	Baltimore Oriole
☐	☑	Barn Swallow
☑	☑	Belted Kingfisher
☐	☑	Black-billed Cuckoo
☐	☑	Black-billed Magpie
☑	☑	Black-capped Chickadee
☐	☑	Black-and-white Warbler
☐	☑	Black-headed Grosbeak
☐	☑	Blue Jay
☐	☑	Bobolink
☐	☑	Brewer's Blackbird
☑	☑	Brown-headed Cowbird
☐	☑	Brown Creeper
☑	☑	Brown Thrasher
☑	☑	Bullock's Oriole
☑	☑	Canada Goose
☑	☑	Cedar Waxwing
☑	☑	Chimney Swift
☐	☑	Chipping Sparrow
☐	☑	Clay-collared Sparrow
☐	☑	Cliff Swallow
☐	☑	Common Grackle
☐	☑	Common Merganser
☐	☑	Common Nighthawk
☐	☐	Common Raven
☑	☑	Common Yellowthroat
☐	☑	Cooper's Hawk
☐	☑	Dickcissel
☑	☑	Downy Woodpecker
☐	☑	Eastern Bluebird
☑	☑	Eastern Kingbird
☐	☑	Eurasian Collared-dove
☑	☑	European Starling
☑	☑	Field Sparrow
☐	☑	Franklin's Gull
☐	☑	Grasshopper Sparrow
☐	☑	Gray Catbird
☑	☑	Great Blue Heron
☐	☑	Great Horned Owl
☐	☑	Hairy Woodpecker
☐	☐	House Finch
☑	☑	House Wren
☐	☑	Killdeer
☐	☑	Lark Bunting
☐	☑	Lark Sparrow
☑	☑	Lazuli Bunting
☑	☑	Least Flycatcher
☐	☑	Mallard
☐	☐	Mountain Bluebird
☑	☑	Mourning Dove
☑	☑	Northern Flicker
☐	☑	Orchard Oriole
☐	☐	Osprey
☑	☑	Ovenbird
☐	☑	Plumbeous Vireo
☐	☑	Red-headed Woodpecker
☐	☐	Red-naped Sapsucker
☐	☑	Red Crossbill
☑	☑	Ring-necked Pheasant
☑	☑	Red-tailed hawk
☐	☑	Rock Dove
☑	☑	Red-winged Blackbird
☑	☑	Red-eyed Vireo
☐	☐	Red-breasted Grosbeak
☐	☑	Say's Phoebe
☐	☑	Savannah Sparrow
☑	☑	Song Sparrow
☐	☑	Spotted Sandpiper
☑	☑	Spotted Towhee
☐	☑	Sharp-shinned Hawk
☐	☑	Swainson's Thrush
☐	☑	Sandhill Crane
☑	☑	Tree Swallow
☐	☑	Turkey Vulture
☐	☑	Upland Sandpiper
☐	☑	Vesper Sparrow
☑	☑	Violet-green Swallow
☑	☑	Warbling Vireo
☐	☑	Western Kingbird
☑	☑	Western Meadowlark
☑	☑	Western Wood-pewee
☑	☑	White-breasted Nuthatch
☐	☑	White-throated Swift
☐	☑	Wild Turkey
☑	☑	Wood Duck
☐	☐	Yellow-bellied Sapsucker
☐	☐	Yellow-billed Cuckoo
☑	☑	Yellow-breasted Chat
☐	☐	Yellow-headed Blackbird
☑	☑	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Treasure	**Upstream River Mile**	278.2
Classification	PCS: Partially confined straight	**Downstream River Mile**	275
General Location	Hysham	**Length**	3.20 mi (5.15 km)
General Comments	Hysham		

Narrative Summary

Reach C5 is located north of Hysham. The reach is a 3.2 mile long Partially Confined Straight reach type, as the river flows straight eastward along the northern bluff line.

There is no mapped bank armor in the reach.

One side channel in the upper part of the reach has had land use encroachment and appears to have potentially been blocked prior to 1950. It is a small seasonal channel, however, and thus may have decayed naturally.

Land use is dominated by agriculture, with 181 acres of pivot irrigation development since 1950. There are about 260 acres of flood irrigated land within the CMZ, but due to the lack of bank armor, none of the CMZ has become restricted.

Two ice jams have been recorded in Reach C5. The first was in January 1997, and the second was a break-up event in mid-March of 2003.

Reach C5 shows a net loss of 15 acres of gravel bars 1950. Most of that loss has been associated with mid-channel bars. About 23 acres of riparian area has been cleared for irrigation, which is 6 percent of the total mapped 1950 riparian zone. There are 22 acres of Russian olive in the reach.

About 19 percent of the total 100-year floodplain has become isolated due to human development. The 5-year floodplain is even more affected; 68 percent of the historic 5-year floodplain is no longer inundated at that frequency. The isolation of the historic 5-year floodplain, due primarily to flow alterations, has been associated with increased development in these areas; currently there are about 380 acres of flood irrigated land within the historic 5-year floodplain. The vast majority of isolated 5-year floodplain area is within flood irrigated fields south of the river. The isolation is due to flow alterations.

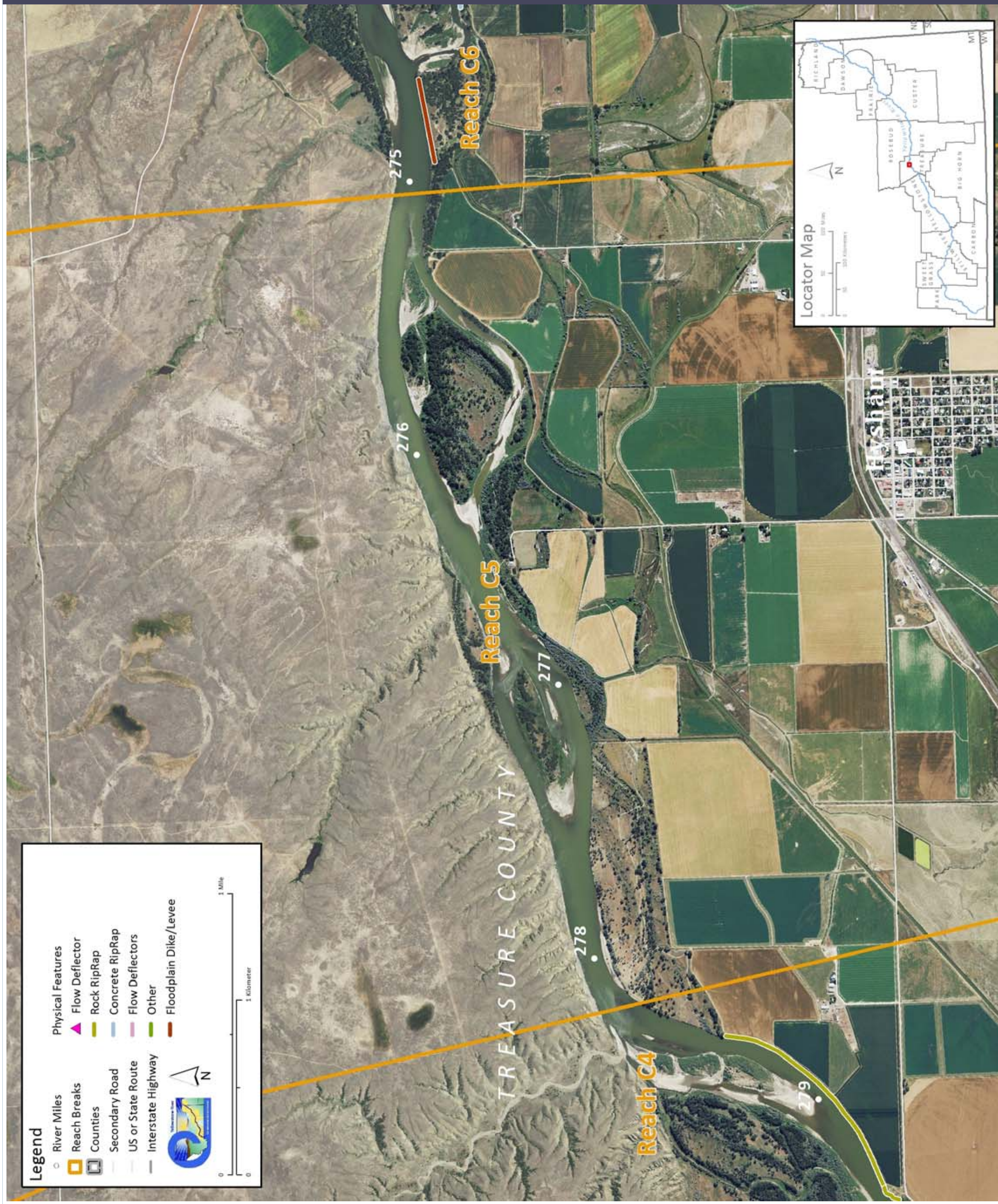
Reach C5 was sampled as part of the avian study. A total of 35 bird species were identified in the reach. One bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) was found, the Ovenbird. Reach C5 has seen a decrease in the forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 41 acres per valley mile of such forest, and that number decreased to 26 acres per valley mile by 2001.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 23 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,630 cfs to 2,960 cfs with human development, a reduction of 36 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,150 cfs under unregulated conditions to 3,320 cfs under regulated conditions at Reach C10 downstream where the analysis begins, a reduction of 46 percent.

CEA-Related observations in Reach C5 include:
•Influence of flow alterations on floodplain inundation

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C5 include:
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	91.0	86.2

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		60,900	76,700	87,100	110,000	120,000	143,000	4,630	3,846
Regulated		47,100	61,300	70,700	91,200	100,000	121,000	2,960	2,227
% Change		-22.66%	-20.08%	-18.83%	-17.09%	-16.67%	-15.38%	-36.07%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	7/14/96 - 9/23/97	B/W		6295000	25300
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/13/2005	color	1-meter pixels	6309000	17700
2005	NAIP	07/12/2005	color	1-meter pixels	6309000	17500
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/30/2009	Color	1-meter pixels	6309000	13800
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/17/2011	Color	1-meter pixels	6309000	54600
2013	NAIP	07/21/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

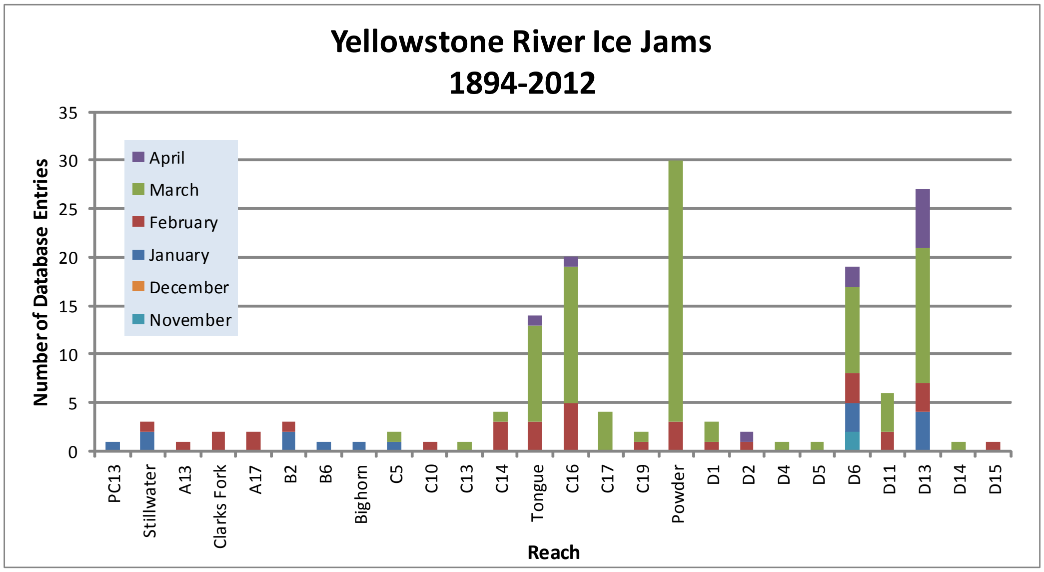
Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
1/2/1997	NA	277	?
3/15/2003	Break-up		?

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	16,729	16,263	1.97	1950 to 1976:	-2.98%
1976	16,403	14,980	1.91	1976 to 1995:	-3.37%
1995	16,646	14,130	1.85	1995 to 2001:	-1.71%
2001	16,646	13,603	1.82	1950 to 2001:	-7.86%
Change 1950 - 2001	**-83**	**-2,660**	**-0.15**		

Length of Side Channels Blocked

Pre-1950s (ft)	8,829
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	321	18.8%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1385		620	
Total Floodplain Area (Ac)	1706		1256	
Total Isolated (Ac)	**321**	**18.8%**	**636**	**67.8%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	88	0	0	**88**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as “Restricted Migration Areas” (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as “Avulsion Potential Zones”.

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
186	371	620	0	0%	339	0	0%

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
257.5	0.0	0.0	0.0	0.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	31	31	31	31	0.8%	0.8%	0.8%	0.8%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	35	47	36	39	0.9%	1.2%	0.9%	1.0%
	Totals	**66**	**78**	**67**	**70**	**1.7%**	**2.0%**	**1.7%**	**1.8%**
Agricultural Land									
	Non-Irrigated	1,408	1,539	1,590	1,572	36.7%	40.1%	41.4%	41.0%
	Irrigated	1,866	1,707	1,665	1,673	48.6%	44.5%	43.4%	43.6%
	Totals	**3,273**	**3,246**	**3,255**	**3,245**	**85.3%**	**84.6%**	**84.8%**	**84.6%**
Channel									
	Channel	436	439	439	446	11.4%	11.5%	11.4%	11.6%
	Totals	**436**	**439**	**439**	**446**	**11.4%**	**11.5%**	**11.4%**	**11.6%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	8	8	8	0.0%	0.2%	0.2%	0.2%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	4	6	6	0.0%	0.1%	0.2%	0.2%
	Totals	**0**	**12**	**15**	**15**	**0.0%**	**0.3%**	**0.4%**	**0.4%**
Transportation									
	Public Road	23	23	23	23	0.6%	0.6%	0.6%	0.6%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	10	10	10	10	0.2%	0.2%	0.2%	0.2%
	Totals	**33**	**33**	**33**	**33**	**0.8%**	**0.8%**	**0.8%**	**0.8%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	11	11	14	14	0.3%	0.3%	0.4%	0.4%
	Urban Commercial	7	7	7	7	0.2%	0.2%	0.2%	0.2%
	Urban Undeveloped	7	7	4	4	0.2%	0.2%	0.1%	0.1%
	Urban Industrial	4	4	4	4	0.1%	0.1%	0.1%	0.1%
	Totals	**30**	**30**	**30**	**30**	**0.8%**	**0.8%**	**0.8%**	**0.8%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	40	181	0.0%	0.0%	1.2%	5.6%	0.0%	1.2%	4.4%	5.6%
	Flood	1,866	1,707	1,626	1,492	57.0%	52.6%	49.9%	46.0%	-4.4%	-2.6%	-4.0%	-11.0%
	Totals	**1,866**	**1,707**	**1,665**	**1,673**	**57.0%**	**52.6%**	**51.2%**	**51.6%**	**-4.4%**	**-1.4%**	**0.4%**	**-5.4%**

Non-Irrigated													
	Multi-Use	1,357	1,539	1,589	1,571	41.4%	47.4%	48.8%	48.4%	6.0%	1.4%	-0.4%	7.0%
	Hay/Pasture	51	0	1	1	1.5%	0.0%	0.0%	0.0%	-1.5%	0.0%	0.0%	-1.5%
	Totals	**1,408**	**1,539**	**1,590**	**1,572**	**43.0%**	**47.4%**	**48.8%**	**48.4%**	**4.4%**	**1.4%**	**-0.4%**	**5.4%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	6.3	0.6	0.9	4.7	2.4	2.4	1.1	8.4	3.0
Max	26.1	59.2	26.5	46.4	85.2	62.0	96.2	29.5	124.3
Average	12.2	14.5	9.0	20.9	29.9	18.3	27.2	20.0	31.6
Sum	97.7	216.9	90.2	146.4	179.1	146.3	163.4	80.0	157.9

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	24.9
Channel to Riparian (acres)	39.6
Riparian Encroachment (acres)	**14.8**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	39.7
1950s Floodplain Mapped as 2011 Channel (Ac)	5.0
Total Recruitment (1950s to 2011)(Ac)	**44.7**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	13.6	43.6	6.9	0.0	**64.0**
Acres/Valley Mile	4.5	14.4	2.3	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	22.36	0.83%	3.12	0.00	1.47	2.02

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	25.6	17.4	4.0%
Bluff Pool	165.7	147.1	33.5%
Secondary Channel		3.1	0.7%
Secondary Channel (Seasonal)	62.8	46.1	10.5%
Channel Crossover	64.8	47.3	10.8%
Side Bar		18.6	4.2%
Mid-channel Bar		6.2	1.4%
Island	119.7	119.7	27.3%
Dry Channel		33.1	7.5%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern   Potential Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
☑	☑	American Robin	☐	☑	Chipping Sparrow	☐	☑	Killdeer	☑	☑	Song Sparrow
☑	☑	American Crow	☐	☑	Clay-collared Sparrow	☐	☑	Lark Bunting	☐	☑	Spotted Sandpiper
☑	☑	American Goldfinch	☐	☑	Cliff Swallow	☐	☑	Lark Sparrow	☑	☑	Spotted Towhee
☐	☑	American Kestrel	☑	☑	Common Grackle	☑	☑	Lazuli Bunting	☐	☑	Sharp-shinned Hawk
☐	☑	American Redstart	☐	☑	Common Merganser	☑	☑	Least Flycatcher	☐	☑	Swainson's Thrush
☐	☑	Bald Eagle	☐	☑	Common Nighthawk	☐	☑	Mallard	☐	☑	Sandhill Crane
☐	☐	Baltimore Oriole	☐	☐	Common Raven	☐	☐	Mountain Bluebird	☑	☑	Tree Swallow
☐	☑	Barn Swallow	☑	☑	Common Yellowthroat	☑	☑	Mourning Dove	☐	☑	Turkey Vulture
☐	☑	Belted Kingfisher	☐	☑	Cooper's Hawk	☑	☑	Northern Flicker	☐	☑	Upland Sandpiper
☐	☑	Black-billed Cuckoo	☐	☑	Dickcissel	☐	☑	Orchard Oriole	☐	☑	Vesper Sparrow
☐	☑	Black-billed Magpie	☑	☑	Downy Woodpecker	☐	☐	Osprey	☐	☑	Violet-green Swallow
☑	☑	Black-capped Chickadee	☐	☑	Eastern Bluebird	☑	☑	Ovenbird	☑	☑	Warbling Vireo
☐	☑	Black-and-white Warbler	☐	☑	Eastern Kingbird	☐	☑	Plumbeous Vireo	☐	☑	Western Kingbird
☐	☑	Black-headed Grosbeak	☐	☑	Eurasian Collared-dove	☐	☑	Red-headed Woodpecker	☑	☑	Western Meadowlark
☐	☑	Blue Jay	☑	☑	European Starling	☐	☐	Red-naped Sapsucker	☑	☑	Western Wood-pewee
☐	☑	Bobolink	☐	☑	Field Sparrow	☐	☑	Red Crossbill	☑	☑	White-breasted Nuthatch
☐	☑	Brewer's Blackbird	☐	☑	Franklin's Gull	☑	☑	Ring-necked Pheasant	☑	☑	White-throated Swift
☑	☑	Brown-headed Cowbird	☐	☑	Grasshopper Sparrow	☑	☑	Red-tailed hawk	☐	☑	Wild Turkey
☐	☑	Brown Creeper	☑	☑	Gray Catbird	☐	☑	Rock Dove	☑	☑	Wood Duck
☐	☑	Brown Thrasher	☑	☑	Great Blue Heron	☐	☑	Red-winged Blackbird	☐	☐	Yellow-bellied Sapsucker
☐	☑	Bullock's Oriole	☑	☑	Great Horned Owl	☑	☑	Red-eyed Vireo	☐	☐	Yellow-billed Cuckoo
☑	☑	Canada Goose	☐	☑	Hairy Woodpecker	☐	☐	Red-breasted Grosbeak	☑	☑	Yellow-breasted Chat
☑	☑	Cedar Waxwing	☐	☐	House Finch	☐	☑	Say's Phoebe	☐	☐	Yellow-headed Blackbird
☐	☑	Chimney Swift	☑	☑	House Wren	☐	☑	Savannah Sparrow	☑	☑	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.

There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

Yellowstone River Reach Narratives — Reach C6

County	Treasure	**Upstream River Mile**	275
Classification	UA: Unconfined anabranching	**Downstream River Mile**	269.4
General Location	Mission Valley	**Length**	5.60 mi (9.01 km)

General Comments Reach C6 is located in Mission Valley and provides a good example of a reach likely impacted by both physical features and hydrologic alterations.

Narrative Summary

Reach C6 is located in the Mission Valley north of Hysham. The reach is a 5.6 mile long Unconfined Anabranching reach type, indicating minimal valley wall influence and extensive side channels and forested islands. In this area the alluvial valley bottom is approximately 2.5 miles wide, and this broad valley has formed in the relatively erodible Cretaceous-age Bearpaw Shale.

There are just over 3,000 feet of bank armor in the reach, which covers 5.1 percent of the total bankline. About 600 feet of a floodplain dike at RM 273.2R appears to have been eroded out since 2001.

Almost 11,000 feet of side channels have been blocked by physical features in the reach since 1950. One floodplain dike that blocked a side channel at RM 227.8L in 2001 was eroded out and has since been rebuilt. Additional side channel length has been lost passively, overall, there has been about a three mile reduction in side channel length in this reach since 1950.

About 20 percent of the total 100-year floodplain has become isolated due to human development. The 5-year floodplain is even more affected; 70 percent of the historic 5-year floodplain is no longer inundated at that frequency. The isolation of the historic 5-year floodplain, due primarily to flow alterations, has been associated with increased development in these areas; currently there are about 650 acres of flood irrigated land and 200 acres of pivot land within the historic 5-year floodplain. The vast majority of isolated 5-year floodplain area is within irrigated fields south of the river, and the isolation appears to be due to both flow alterations and agricultural dikes.

Land use is dominated by agriculture, with 188 acres of pivot irrigation development since 1950. There are about 260 acres of flood irrigated land within the CMZ, but due to the lack of bank armor, none of the CMZ has become restricted.

Riparian mapping data show a net gain of 158 acres of woody vegetation into the active channel corridor since 1950. This has occurred both on migrating point bars that have become vegetated, as well as within abandoned side channels. Since 1950, the total area of open timber increased by approximately 250 acres. There are 40 acres of Russian olive in the reach.

Reach C6 was sampled as part of the fisheries study. A total of 26 fish species were sampled in the reach.

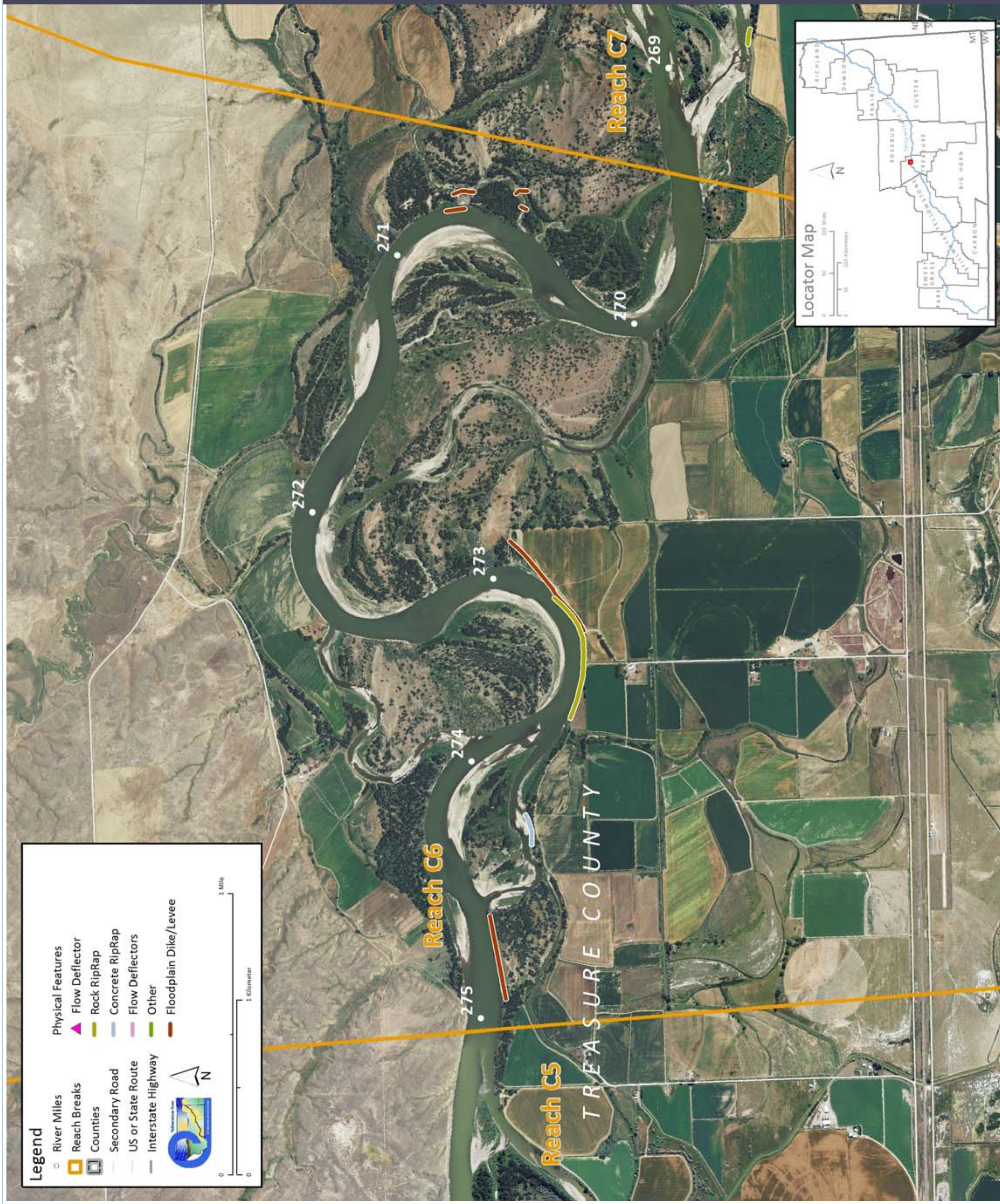
Reach C6 was sampled as part of the avian study. A total of 32 bird species were identified in the reach. Two bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were found, the Ovenbird, and the Chimney Swift. In contrast to most reaches, Reach C6 has seen an increase in the forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 55 acres per valley mile of such forest, and that number increased to 106 acres per valley mile by 2001.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 23 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,630 cfs to 2,960 cfs with human development, a reduction of 36 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,150 cfs under unregulated conditions to 3,320 cfs under regulated conditions at Reach C10 downstream where the analysis begins, a reduction of 46 percent.

CEA-Related observations in Reach C6 include:
•Active and passive loss of thousands of feet of side channel
•Reconstruction of side-channel blockage following its failure post-2001.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C6 include:
•Side channel reactivation at RM 275R and RM 271L
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	85.4	89.4

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		61,000	76,800	87,200	110,000	120,000	143,000	4,640	3,846
Regulated		47,000	61,300	70,700	91,300	100,000	121,000	2,970	2,227
% Change		-22.95%	-20.18%	-18.92%	-17.00%	-16.67%	-15.38%	-35.99%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	7/14/96 - 9/23/97	B/W		6295000	25300
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/12/2005	color	1-meter pixels	6309000	17500
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/30/2009	Color	1-meter pixels	6309000	13800
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/17/2011	Color	1-meter pixels	6309000	54600
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/21/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	2,478	4.1%	2,478	4.1%	0
	Concrete RipRap	574	1.0%	574	1.0%	0
	Feature Type Totals	**3,052**	**5.1%**	**3,052**	**5.1%**	**0**
Floodplain Control						
	Floodplain Dike/Levee	4,123	6.9%	4,501	7.5%	378
	Feature Type Totals	**4,123**	**6.9%**	**4,501**	**7.5%**	**378**
	Reach Totals	**7,175**	**12.0%**	**7,553**	**12.6%**	**378**

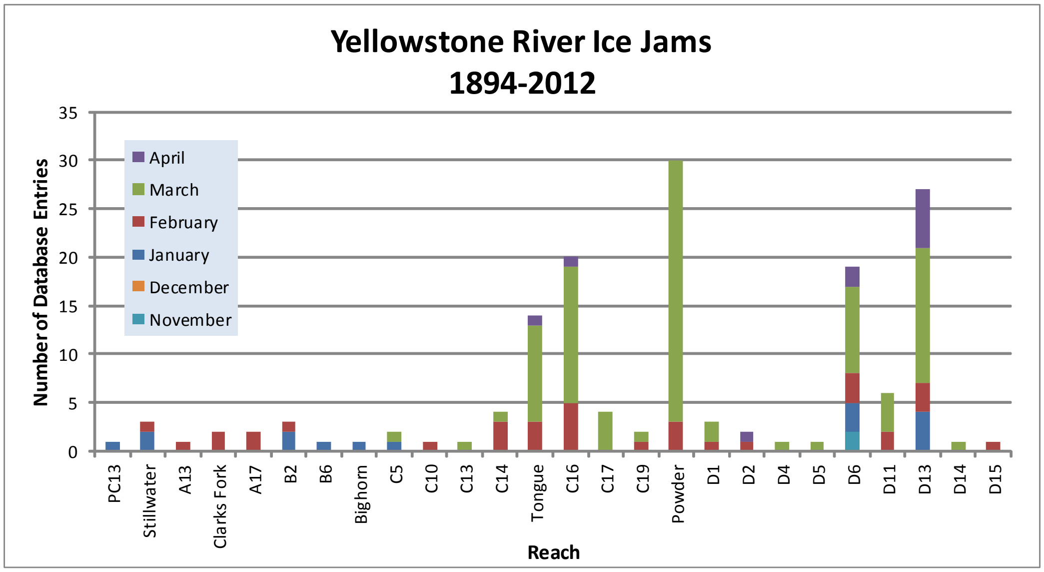
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	574	0	0	0	0	0	0	0
Rock RipRap	2,476	0	0	0	0	0	0	0
Totals	**3,050**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	26,335	41,916	2.59	1950 to 1976:	2.64%
1976	28,910	47,992	2.66	1976 to 1995:	-24.31%
1995	29,871	30,274	2.01	1995 to 2001:	-7.09%
2001	29,871	26,011	1.87	1950 to 2001:	-27.82%
Change 1950 - 2001	**3,536**	**-15,905**	**-0.72**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	10,910

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	159	4.5%		
Agriculture (generally relates to field boundaries)	487	13.7%		
Agriculture (isloated by canal or large ditch)	3	0.1%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	82	2.3%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	2838		1255	
Total Floodplain Area (Ac)	3570		2919	
Total Isolated (Ac)	**732**	**20.5%**	**1664**	**70.2%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	162	0	0	**162**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
325	651	1,982	124	6%	100	52	52%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Irrigated	62	3.0%
Dike/Levee			
	Non-Irrigated	46	2.2%
	Irrigated	68	3.3%
	Totals	**176**	**8.5%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
268.3	0.0	0.0	0.0	0.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	34	43	48	48	0.7%	0.9%	1.0%	1.0%
	Totals	**34**	**43**	**48**	**48**	**0.7%**	**0.9%**	**1.0%**	**1.0%**
Agricultural Land									
	Non-Irrigated	1,646	1,822	2,065	2,031	34.8%	38.5%	43.6%	42.9%
	Irrigated	1,754	1,535	1,555	1,554	37.0%	32.4%	32.8%	32.8%
	Totals	**3,401**	**3,357**	**3,619**	**3,584**	**71.8%**	**70.9%**	**76.4%**	**75.7%**
Channel									
	Channel	1,285	1,320	1,052	1,087	27.1%	27.9%	22.2%	22.9%
	Totals	**1,285**	**1,320**	**1,052**	**1,087**	**27.1%**	**27.9%**	**22.2%**	**22.9%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	15	15	15	15	0.3%	0.3%	0.3%	0.3%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	1	1	1	1	0.0%	0.0%	0.0%	0.0%
	Totals	**16**	**17**	**17**	**17**	**0.3%**	**0.4%**	**0.4%**	**0.4%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	19	188	0.0%	0.0%	0.5%	5.2%	0.0%	0.5%	4.7%	5.2%
	Flood	1,754	1,535	1,536	1,366	51.6%	45.7%	42.4%	38.1%	-5.9%	-3.3%	-4.3%	-13.5%
	Totals	**1,754**	**1,535**	**1,555**	**1,554**	**51.6%**	**45.7%**	**43.0%**	**43.3%**	**-5.9%**	**-2.8%**	**0.4%**	**-8.2%**

Non-Irrigated													
	Multi-Use	1,602	1,822	2,063	2,031	47.1%	54.3%	57.0%	56.7%	7.2%	2.7%	-0.3%	9.5%
	Hay/Pasture	44	0	2	0	1.3%	0.0%	0.1%	0.0%	-1.3%	0.1%	-0.1%	-1.3%
	Totals	**1,646**	**1,822**	**2,065**	**2,031**	**48.4%**	**54.3%**	**57.0%**	**56.7%**	**5.9%**	**2.8%**	**-0.4%**	**8.2%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.8	0.1	2.0	1.8	1.6	1.6	1.0	1.5	3.6
Max	19.2	48.2	51.2	167.9	173.4	156.2	86.1	89.6	165.2
Average	5.5	10.6	10.7	41.0	40.6	45.5	32.6	24.4	68.7
Sum	105.2	274.6	160.3	738.3	730.7	682.9	163.0	219.2	412.3

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	119.1
Channel to Riparian (acres)	277.4
Riparian Encroachment (acres)	**158.3**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	278.1
1950s Floodplain Mapped as 2011 Channel (Ac)	21.2
Total Recruitment (1950s to 2011)(Ac)	**299.3**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	19.0	89.1	22.5	0.0	**130.5**
Acres/Valley Mile	5.5	25.8	6.5	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	40.00	0.93%	7.06	0.48	7.42	5.96

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
✔	✔	Bigmouth buffalo
	✔	Black bullhead
✔	✔	Black crappie
	✔	Blue sucker
	✔	Bluegill
✔	✔	Brook stickleback
	✔	Brown trout
	✔	Burbot
		Catfish species
✔	✔	Channel catfish
✔	✔	Common carp
	✔	Creek chub
✔	✔	Emerald shiner
✔	✔	Fathead minnow
✔	✔	Flathead chub
✔	✔	Freshwater drum
✔	✔	Goldeye
✔	✔	Green sunfish
	✔	Lake chub
	✔	Largemouth bass
✔	✔	Longnose dace
✔	✔	Longnose sucker
✔	✔	Minnow species
		Mottled sculpin
✔	✔	Mountain sucker
	✔	Mountain whitefish
	✔	Northern pike
✔	✔	Northern plains killifish
		Northern redbelly dace
		Pallid sturgeon
	✔	Pumpkinseed
		Rainbow trout
✔	✔	River carpsucker
	✔	Rock bass
✔	✔	Sand shiner
	✔	Sauger
✔	✔	Shorthead redhorse
		Shortnose gar
	✔	Shovelnose sturgeon
		Sicklefin chub
✔	✔	Smallmouth bass
✔	✔	Smallmouth buffalo
✔	✔	Stonecat
		Sturgeon chub
✔	✔	Sucker species
	✔	Sunfish species
✔	✔	Walleye
✔	✔	Western silvery minnow
		White bass
	✔	White crappie
✔	✔	White sucker
	✔	Yellow bullhead
		Yellow perch

Low Flow Fisheries Habitat Mapping

Habitat	Bankfull (2001 Acres)	Low Flow (2001 Acres)	% of Low Flow
Scour Pool	242.1	158.7	15.1%
Rip Rap Bottom	98.9	68.6	6.5%
Secondary Channel		15.2	1.4%
Secondary Channel (Seasonal)	112.7	79.8	7.6%
Channel Crossover	95.2	74.6	7.1%
Point Bar		104.2	9.9%
Side Bar		7.6	0.7%
Mid-channel Bar		14.0	1.3%
Island	502.6	502.6	47.8%
Dry Channel		26.2	2.5%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern   Potential Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
✓	✓	American Robin		✓	Chipping Sparrow		✓	Killdeer	✓	✓	Song Sparrow
	✓	American Crow		✓	Clay-collared Sparrow		✓	Lark Bunting		✓	Spotted Sandpiper
		American Goldfinch		✓	Cliff Swallow	✓	✓	Lark Sparrow	✓	✓	Spotted Towhee
✓	✓	American Kestrel		✓	Common Grackle	✓	✓	Lazuli Bunting		✓	Sharp-shinned Hawk
	✓	American Redstart		✓	Common Merganser	✓	✓	Least Flycatcher		✓	Swainson's Thrush
	✓	Bald Eagle		✓	Common Nighthawk		✓	Mallard		✓	Sandhill Crane
		Baltimore Oriole			Common Raven			Mountain Bluebird	✓	✓	Tree Swallow
	✓	Barn Swallow	✓	✓	Common Yellowthroat	✓	✓	Mourning Dove		✓	Turkey Vulture
	✓	Belted Kingfisher		✓	Cooper's Hawk	✓	✓	Northern Flicker		✓	Upland Sandpiper
	✓	Black-billed Cuckoo		✓	Dickcissel		✓	Orchard Oriole		✓	Vesper Sparrow
	✓	Black-billed Magpie	✓	✓	Downy Woodpecker			Osprey		✓	Violet-green Swallow
✓	✓	Black-capped Chickadee		✓	Eastern Bluebird	✓	✓	Ovenbird	✓	✓	Warbling Vireo
	✓	Black-and-white Warbler	✓	✓	Eastern Kingbird		✓	Plumbeous Vireo	✓	✓	Western Kingbird
	✓	Black-headed Grosbeak		✓	Eurasian Collared-dove		✓	Red-headed Woodpecker		✓	Western Meadowlark
✓	✓	Blue Jay	✓	✓	European Starling			Red-naped Sapsucker	✓	✓	Western Wood-pewee
	✓	Bobolink		✓	Field Sparrow	✓	✓	Red Crossbill	✓	✓	White-breasted Nuthatch
	✓	Brewer's Blackbird		✓	Franklin's Gull		✓	Ring-necked Pheasant		✓	White-throated Swift
	✓	Brown-headed Cowbird		✓	Grasshopper Sparrow	✓	✓	Red-tailed hawk		✓	Wild Turkey
	✓	Brown Creeper	✓	✓	Gray Catbird		✓	Rock Dove		✓	Wood Duck
	✓	Brown Thrasher		✓	Great Blue Heron		✓	Red-winged Blackbird			Yellow-bellied Sapsucker
✓	✓	Bullock's Oriole		✓	Great Horned Owl	✓	✓	Red-eyed Vireo			Yellow-billed Cuckoo
	✓	Canada Goose	✓	✓	Hairy Woodpecker			Red-breasted Grosbeak	✓	✓	Yellow-breasted Chat
✓	✓	Cedar Waxwing			House Finch		✓	Say's Phoebe			Yellow-headed Blackbird
✓	✓	Chimney Swift	✓	✓	House Wren		✓	Savannah Sparrow	✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Treasure	**Upstream River Mile**	269.4
Classification	UA: Unconfined anabranching	**Downstream River Mile**	260.3
General Location	Mission Valley	**Length**	9.10 mi (14.65 km)
General Comments	Mission Valley		

Narrative Summary

Reach C7 is 9.1 miles long and is located in the Mission Valley downstream of Hysham. It is an Unconfined Anabranching reach type, which indicates little in the way of valley wall influence coupled with extensive side channels and forested islands. The Mission Valley owes its width to the presence of the Bearpaw Shale in the valley wall. Because this Cretaceous-age shale is relatively erodible and prone to mass failure, over time the river has been able to erode the valley wall more easily than in other reaches, creating the large distinct valleys present today. Because the Mission and Hammond Valleys are so wide, the river developed a complex series of channels and an expansive riparian forest. These reaches are especially rich in terms of aquatic and riparian habitat extent, diversity, and geomorphic complexity.

Just over 2,000 feet of rock riprap lines the banks in Reach C7, protecting 2.3 percent of the bankline.

Prior to 1950 about 4,200 feet of side channel had been blocked in Reach C7, and since then, floodplain dikes have blocked another three miles of side channel. Blocked side channels are located at RM 270.8L, RM 263.5R, and RM 261R. Even with all of the blockages, Reach C7 still has on the order of 17 miles of functional side channel length.

Reach C7 appears to be experiencing an active major avulsion just north of Sanders, where an anabranching channel has been developing into a primary channel over the last decade. As rerouting of the river would shorten the main thread by approximately 1.5 miles, an avulsion is very likely to occur in this area over the next several years. The rate at which the anabranching side channel fully captures the main thread will depend on flood events, as floods will accelerate the avulsion process. This avulsion would take pressure off of the main channel to the south, which is currently threatening the rail line at RM 264.8R and RM 266.2R.

About 9 percent of the total 100-year floodplain has become isolated due to human development in Reach C7. The 5-year floodplain is even more affected; 41 percent of the historic 5-year floodplain is no longer inundated at that frequency. The isolation of the historic 5-year floodplain, due primarily to flow alterations, has been associated with increased development in these areas; currently there are about 95 acres of flood irrigated land and 56 acres of pivot land within the historic 5-year floodplain. Much of the isolated 5-year floodplain area is within the active stream corridor and riparian zone however, exemplifying the potential impacts of flow alterations on frequent floodplain inundation.

Land use is dominated by agriculture, with 277 acres of pivot irrigation development since 1950. There are about 350 acres of flood irrigated land and 31 acres of pivot within the CMZ, but only 4 percent of the CMZ is restricted by physical features.

Riparian mapping data show a net gain of 780 acres of woody vegetation into the active channel corridor since 1950. This has occurred both on migrating point bars that have become vegetated, as well as within abandoned side channels. Reach C7 has about 90 acres of wetland per valley mile, which makes it one of the most concentrated wetland areas in the corridor. There are also 164 acres of Russian olive in the reach.

Reach C7 was sampled as part of the fisheries study. A total of 27 fish species were sampled in the reach, including Sauger, which are recognized by the Montana Natural Heritage Program as a Species of Concern (SOC).

Reach C7 was sampled as part of the avian study. A total of 69 bird species were identified in the reach. Four bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were found, the Black and White Warbler, the Plumbeous Vireo, the Ovenbird, and the Chimney Swift. Two Species of Concern (SOC) were identified, the Black Billed Cuckoo and the Bobolink. Brown Headed Cowbirds were also present. Reach C7 has seen an increase in the forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 86 acres per valley mile of such forest, and that number increased to 102 acres per valley mile by 2001.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 23 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,680 cfs to 2,990 cfs with human development, a reduction of 36 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,150 cfs under unregulated conditions to 3,320 cfs under regulated conditions at Reach C10 downstream where the analysis begins, a reduction of 46 percent.

CEA-Related observations in Reach C7 include:
•Active and passive loss of thousands of feet of side channel

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C7 include:
•Side channel reactivation at RM 270.8L, RM 263.5R, and RM 261R
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	76.3	95.0

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		61,100	77,000	87,400	110,000	120,000	144,000	4,680	3,846
Regulated		47,000	61,300	70,700	91,400	100,000	121,000	2,990	2,227
% Change		-23.08%	-20.39%	-19.11%	-16.91%	-16.67%	-15.97%	-36.11%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	7/14/96 - 9/20/97	B/W		6295000	25300
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/12/2005	color	1-meter pixels	6309000	17500
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	8/11/2009	Color	1-meter pixels	6309000	12900
2009	NAIP	7/30/2009	Color	1-meter pixels	6309000	13800
2009	NAIP	7/25/2009	Color	1-meter pixels	6309000	13600
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/20/2013	color	1-meter pixels	6309000	
2013	NAIP	07/21/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	2,173	2.3%	2,173	2.3%	0
	Feature Type Totals	**2,173**	**2.3%**	**2,173**	**2.3%**	**0**
Floodplain Control						
	Floodplain Dike/Levee	429	0.4%	429	0.4%	0
	Feature Type Totals	**429**	**0.4%**	**429**	**0.4%**	**0**
	Reach Totals	**2,602**	**2.7%**	**2,602**	**2.7%**	**0**

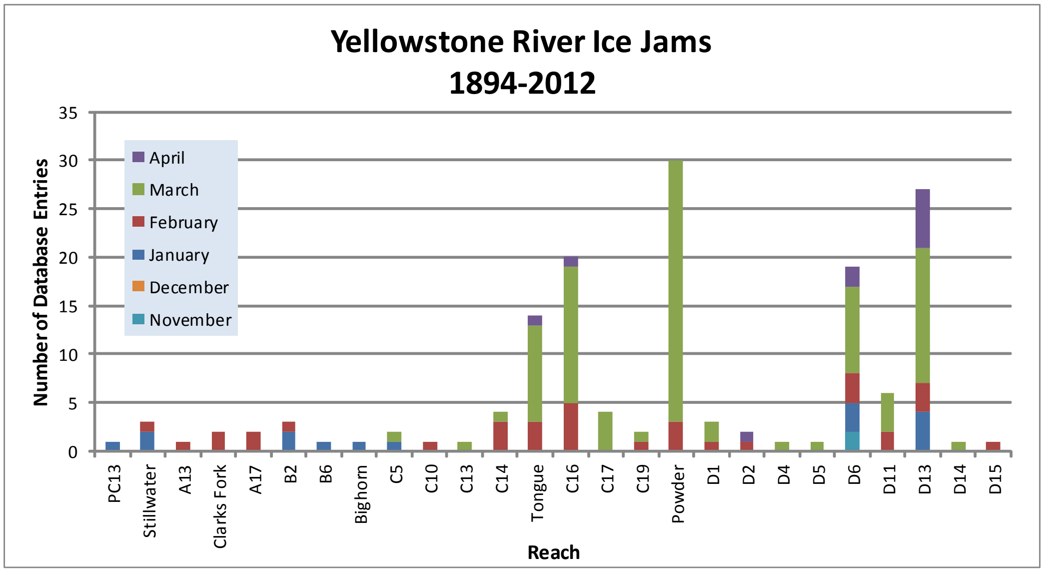
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	2,171	0	0	0	0	0	0	0
Totals	**2,171**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	44,646	91,763	3.06	1950 to 1976:	9.52%
1976	47,069	110,437	3.35	1976 to 1995:	-22.68%
1995	50,128	79,561	2.59	1995 to 2001:	11.49%
2001	48,131	90,696	2.88	1950 to 2001:	-5.60%
Change 1950 - 2001	**3,485**	**-1,066**	**-0.17**		

Length of Side Channels Blocked

Pre-1950s (ft)	4,230
Post-1950s (ft)	15,593

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	275	6.5%		
Agriculture (generally relates to field boundaries)	16	0.4%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	88	2.1%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	3849		2820	
Total Floodplain Area (Ac)	4227		3928	
Total Isolated (Ac)	**378**	**8.9%**	**1107**	**40.9%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	121	0	104	**225**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
506	1,012	4,478	173	4%	241	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	101	2.1%
RipRap			
	Irrigated	72	1.5%
	Totals	**173**	**3.7%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
351.2	0.0	30.8	0.0	21.6

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	10	10	10	10	0.1%	0.1%	0.1%	0.1%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	67	91	118	118	0.7%	1.0%	1.3%	1.3%
	Totals	**77**	**101**	**128**	**128**	**0.8%**	**1.1%**	**1.4%**	**1.4%**
Agricultural Land									
	Non-Irrigated	3,501	3,872	4,499	4,468	37.4%	41.3%	48.0%	47.7%
	Irrigated	3,277	2,473	2,255	2,228	35.0%	26.4%	24.1%	23.8%
	Totals	**6,778**	**6,345**	**6,755**	**6,696**	**72.3%**	**67.7%**	**72.1%**	**71.4%**
Channel									
	Channel	2,416	2,821	2,378	2,437	25.8%	30.1%	25.4%	26.0%
	Totals	**2,416**	**2,821**	**2,378**	**2,437**	**25.8%**	**30.1%**	**25.4%**	**26.0%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	1	8	8	0.0%	0.0%	0.1%	0.1%
	Totals	**0**	**1**	**8**	**8**	**0.0%**	**0.0%**	**0.1%**	**0.1%**
Transportation									
	Public Road	62	62	62	62	0.7%	0.7%	0.7%	0.7%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	40	42	42	42	0.4%	0.4%	0.4%	0.4%
	Totals	**102**	**104**	**104**	**104**	**1.1%**	**1.1%**	**1.1%**	**1.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	56	276	0.0%	0.0%	0.8%	4.1%	0.0%	0.8%	3.3%	4.1%
	Flood	3,277	2,473	2,199	1,951	48.3%	39.0%	32.6%	29.1%	-9.4%	-6.4%	-3.4%	-19.2%
	Totals	**3,277**	**2,473**	**2,255**	**2,228**	**48.3%**	**39.0%**	**33.4%**	**33.3%**	**-9.4%**	**-5.6%**	**-0.1%**	**-15.1%**

Non-Irrigated												
Multi-Use	3,451	3,806	4,336	4,393	50.9%	60.0%	64.2%	65.6%	9.1%	4.2%	1.4%	14.7%
Hay/Pasture	50	66	164	75	0.7%	1.0%	2.4%	1.1%	0.3%	1.4%	-1.3%	0.4%
Totals	**3,501**	**3,872**	**4,499**	**4,468**	**51.7%**	**61.0%**	**66.6%**	**66.7%**	**9.4%**	**5.6%**	**0.1%**	**15.1%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.2	0.1	0.0	0.7	1.0	0.8	1.9	2.0	1.5
Max	82.2	38.9	65.8	358.0	226.4	275.4	259.3	195.1	376.3
Average	10.4	8.2	10.6	74.6	54.7	47.7	58.8	29.5	61.9
Sum	396.3	448.9	435.6	1,491.6	1,639.9	1,431.2	588.3	502.1	927.9

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	395.3
Channel to Riparian (acres)	564.8
Riparian Encroachment (acres)	**169.5**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	570.1
1950s Floodplain Mapped as 2011 Channel (Ac)	215.2
Total Recruitment (1950s to 2011)(Ac)	**785.3**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	15.7	406.2	130.4	0.0	**552.3**
Acres/Valley Mile	2.5	65.4	21.0	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	164.35	2.08%	10.40	2.29	35.11	36.34

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
	✓	Bigmouth buffalo
	✓	Black bullhead
✓	✓	Black crappie
	✓	Blue sucker
✓	✓	Bluegill
✓	✓	Brook stickleback
	✓	Brown trout
✓	✓	Burbot
		Catfish species
✓	✓	Channel catfish
✓	✓	Common carp
	✓	Creek chub
✓	✓	Emerald shiner
✓	✓	Fathead minnow
✓	✓	Flathead chub
✓	✓	Freshwater drum
✓	✓	Goldeye
	✓	Green sunfish
	✓	Lake chub
	✓	Largemouth bass
✓	✓	Longnose dace
✓	✓	Longnose sucker
✓	✓	Minnow species
		Mottled sculpin
✓	✓	Mountain sucker
	✓	Mountain whitefish
	✓	Northern pike
✓	✓	Northern plains killifish
		Northern redbelly dace
		Pallid sturgeon
	✓	Pumpkinseed
		Rainbow trout
✓	✓	River carpsucker
	✓	Rock bass
✓	✓	Sand shiner
✓	✓	Sauger
✓	✓	Shorthead redhorse
		Shortnose gar
	✓	Shovelnose sturgeon
		Sicklefin chub
✓	✓	Smallmouth bass
✓	✓	Smallmouth buffalo
✓	✓	Stonecat
		Sturgeon chub
✓	✓	Sucker species
	✓	Sunfish species
	✓	Walleye
✓	✓	Western silvery minnow
		White bass
✓	✓	White crappie
✓	✓	White sucker
	✓	Yellow bullhead
		Yellow perch

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	377.7	279.2	11.7%
Rip Rap Bottom	46.3	34.2	1.4%
Bluff Pool	53.5	35.9	1.5%
Secondary Channel	147.9	81.2	3.4%
Secondary Channel (Seasonal)	360.7	262.0	11.0%
Channel Crossover	231.0	153.2	6.4%
Point Bar		72.9	3.1%
Side Bar		127.7	5.4%
Mid-channel Bar		36.7	1.5%
Island	1,161.0	1,161.6	48.8%
Dry Channel		133.4	5.6%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern

Potential Species of Concern

Reach	Region	Species
✓	✓	American Robin
✓	✓	American Crow
✓	✓	American Goldfinch
✓	✓	American Kestrel
✓	✓	American Redstart
✓	✓	Bald Eagle
		Baltimore Oriole
✓	✓	Barn Swallow
	✓	Belted Kingfisher
✓	✓	Black-billed Cuckoo
✓	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
✓	✓	Black-and-white Warbler
✓	✓	Black-headed Grosbeak
✓	✓	Blue Jay
✓	✓	Bobolink
	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
	✓	Brown Creeper
✓	✓	Brown Thrasher
✓	✓	Bullock's Oriole
✓	✓	Canada Goose
✓	✓	Cedar Waxwing
✓	✓	Chimney Swift
	✓	Chipping Sparrow
✓	✓	Clay-collared Sparrow
✓	✓	Cliff Swallow
✓	✓	Common Grackle
✓	✓	Common Merganser
✓	✓	Common Nighthawk
		Common Raven
✓	✓	Common Yellowthroat
✓	✓	Cooper's Hawk
	✓	Dickcissel
✓	✓	Downy Woodpecker
	✓	Eastern Bluebird
✓	✓	Eastern Kingbird
✓	✓	Eurasian Collared-dove
✓	✓	European Starling
✓	✓	Field Sparrow
	✓	Franklin's Gull
✓	✓	Grasshopper Sparrow
✓	✓	Gray Catbird
	✓	Great Blue Heron
✓	✓	Great Horned Owl
✓	✓	Hairy Woodpecker
		House Finch
✓	✓	House Wren
✓	✓	Killdeer
	✓	Lark Bunting
✓	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
✓	✓	Mallard
		Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
✓	✓	Orchard Oriole
		Osprey
✓	✓	Ovenbird
✓	✓	Plumbeous Vireo
✓	✓	Red-headed Woodpecker
		Red-naped Sapsucker
✓	✓	Red Crossbill
✓	✓	Ring-necked Pheasant
✓	✓	Red-tailed hawk
	✓	Rock Dove
✓	✓	Red-winged Blackbird
✓	✓	Red-eyed Vireo
		Red-breasted Grosbeak
✓	✓	Say's Phoebe
✓	✓	Savannah Sparrow
✓	✓	Song Sparrow
✓	✓	Spotted Sandpiper
✓	✓	Spotted Towhee
	✓	Sharp-shinned Hawk
	✓	Swainson's Thrush
	✓	Sandhill Crane
✓	✓	Tree Swallow
	✓	Turkey Vulture
	✓	Upland Sandpiper
	✓	Vesper Sparrow
✓	✓	Violet-green Swallow
✓	✓	Warbling Vireo
✓	✓	Western Kingbird
✓	✓	Western Meadowlark
✓	✓	Western Wood-pewee
✓	✓	White-breasted Nuthatch
	✓	White-throated Swift
✓	✓	Wild Turkey
✓	✓	Wood Duck
		Yellow-bellied Sapsucker
		Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
		Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Treasure	**Upstream River Mile**	260.3
Classification	PCS: Partially confined straight	**Downstream River Mile**	253.8
General Location	Rosebud/Treasure County Line	**Length**	6.50 mi (10.46 km)
General Comments	Rosebud/Treasure County Line		

Narrative Summary

Reach C8 is 9.1 miles long and is located on the Rosebud/Treasure County line. It is a Partially Confined Straight reach type, as the river flows straight eastward along the northern bluff line.

There is approximately 4,100 feet of rock riprap in the reach, 800 feet of which was built since 2001. About 6 percent of the total bankline is armored.

Prior to 1950 about 2,300 feet of side channel had been blocked in Reach C8, and since then, floodplain dikes have blocked another 8,500 feet of side channel. Blocked side channels are located at RM 260R and RM 257R. Side channels have also been passively lost; since 1950, there has been a total loss of 2.6 miles of side channel in Reach C8. About four miles of active side channel remain.

About 35 percent of the total 100-year floodplain has become isolated due to human development. Most of the isolation is due to flow alterations. The 5-year floodplain is even more affected; 55 percent of the historic 5-year floodplain is no longer inundated at that frequency. The isolation of the historic 5-year floodplain, due primarily to flow alterations, has been associated with increased development in these areas; currently there are about 240 acres of flood irrigated land within the historic 5-year floodplain. Most of the isolated 5-year floodplain area is occupied by flood irrigated fields south of the river.

Land use is dominated by agriculture, with 342 acres of pivot irrigation development since 1950. There are about 178 acres of flood irrigated land and 12 acres of pivot within the CMZ, and 10 percent of the CMZ is restricted by physical features.

Riparian recruitment analyses show that between 1950 and 2001, there was 193 total acres of riparian colonization in the reach. Taking into account losses due to erosion, there was still a net gain of 94 acres of woody vegetation into the active channel corridor since 1950. This has occurred both on migrating point bars that have become vegetated, as well as within abandoned side channels. The extent of closed timber has increased from 293 acres in 1950 to 604 acres in 2001. There are 43 acres of Russian olive in the reach.

Reach C8 was sampled as part of the fisheries study. A total of 30 fish species were sampled in the reach, including Sauger, which are recognized by the Montana Natural Heritage Program as a Species of Concern (SOC).

Reach C8 was sampled as part of the avian study. A total of 37 bird species were identified in the reach. Two bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were found, the Ovenbird and the Chimney Swift. Reach C8 has seen an increase in the forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 51 acres per valley mile of such forest, and that number increased to 61 acres per valley mile by 2001.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 23 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,680 cfs to 2,990 cfs with human development, a reduction of 36 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,150 cfs under unregulated conditions to 3,320 cfs under regulated conditions at Reach C10 downstream where the analysis begins, a reduction of 46 percent.

CEA-Related observations in Reach C8 include:
•Active and passive loss of thousands of feet of side channel

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C8 include:
•Side channel reactivation at RM 260R and RM 257R
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	69.8	104.1

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		61,100	77,100	87,500	111,000	120,000	144,000	4,680	3,846
Regulated		47,000	61,300	70,700	91,400	100,000	122,000	2,990	2,227
% Change		-23.08%	-20.49%	-19.20%	-17.66%	-16.67%	-15.28%	-36.11%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	7/14/96 - 6/13/96	B/W		6295000	25300
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/12/2005	color	1-meter pixels	6309000	17500
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	8/11/2009	Color	1-meter pixels	6309000	12900
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/21/2013	color	1-meter pixels	6309000	
2013	NAIP	07/20/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	3,286	4.8%	4,093	6.0%	807
	Flow Deflectors	0	0.0%	52	0.1%	52
	Feature Type Totals	**3,286**	**4.8%**	**4,145**	**6.1%**	**859**
Floodplain Control						
	Floodplain Dike/Levee	1,447	2.1%	1,447	2.1%	0
	Feature Type Totals	**1,447**	**2.1%**	**1,447**	**2.1%**	**0**
	Reach Totals	**4,734**	**6.9%**	**5,592**	**8.2%**	**859**

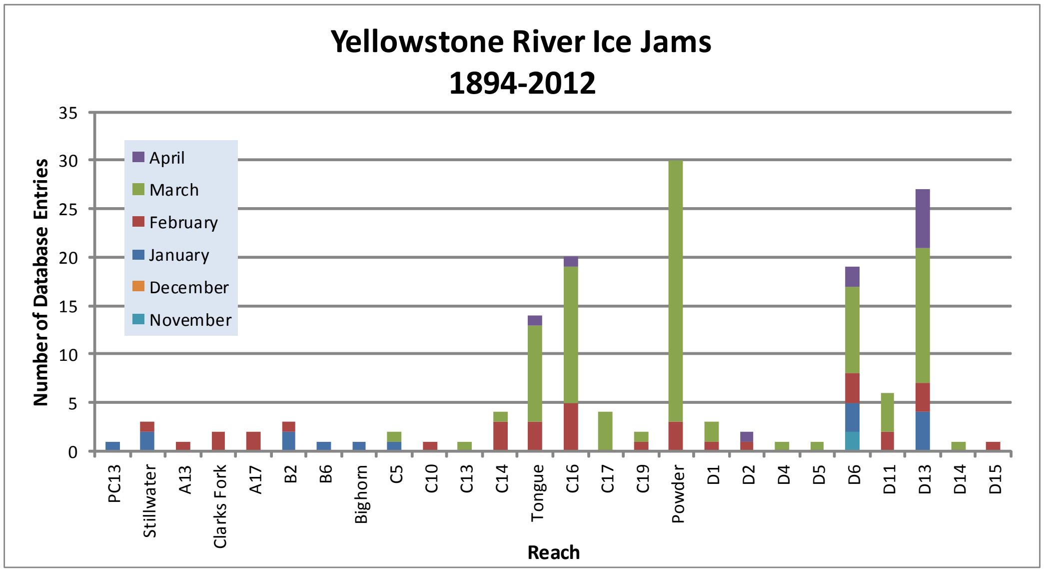
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	3,287	0	0	0	0	0	0	0
Totals	**3,287**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	34,703	34,247	1.99	1950 to 1976:	-12.94%
1976	33,984	24,802	1.73	1976 to 1995:	-2.02%
1995	34,391	23,896	1.69	1995 to 2001:	-5.54%
2001	34,218	20,560	1.60	1950 to 2001:	-19.43%
Change 1950 - 2001	**-485**	**-13,687**	**-0.39**		

Length of Side Channels Blocked

Pre-1950s (ft)	2,323
Post-1950s (ft)	8,494

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	665	26.8%		
Agriculture (generally relates to field boundaries)	35	1.4%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	11	0.5%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	186	7.5%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1581		1172	
Total Floodplain Area (Ac)	2479		1843	
Total Isolated (Ac)	**898**	**36.2%**	**671**	**54.9%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	66	0	0	**67**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
216	433	1,536	134	9%	164	32	20%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Non-Irrigated	151	8.9%
	Irrigated	15	0.9%
	Totals	**167**	**9.8%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
177.9	0.0	11.7	0.0	0.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	40	69	101	105	0.5%	0.9%	1.4%	1.4%
	Totals	**40**	**69**	**101**	**105**	**0.5%**	**0.9%**	**1.4%**	**1.4%**
Agricultural Land									
	Non-Irrigated	3,338	2,946	3,338	2,985	45.7%	40.3%	45.7%	40.8%
	Irrigated	2,808	3,010	3,019	3,125	38.4%	41.2%	41.3%	42.8%
	Totals	**6,146**	**5,956**	**6,357**	**6,110**	**84.1%**	**81.5%**	**87.0%**	**83.6%**
Channel									
	Channel	1,027	1,188	754	998	14.0%	16.3%	10.3%	13.7%
	Totals	**1,027**	**1,188**	**754**	**998**	**14.0%**	**16.3%**	**10.3%**	**13.7%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	67	67	67	67	0.9%	0.9%	0.9%	0.9%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	31	31	31	31	0.4%	0.4%	0.4%	0.4%
	Totals	**98**	**98**	**98**	**98**	**1.3%**	**1.3%**	**1.3%**	**1.3%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	142	342	0.0%	0.0%	2.2%	5.6%	0.0%	2.2%	3.4%	5.6%
	Flood	2,808	3,010	2,877	2,783	45.7%	50.5%	45.3%	45.6%	4.8%	-5.3%	0.3%	-0.1%
	Totals	**2,808**	**3,010**	**3,019**	**3,125**	**45.7%**	**50.5%**	**47.5%**	**51.2%**	**4.8%**	**-3.0%**	**3.7%**	**5.5%**

Non-Irrigated													
	Multi-Use	3,005	2,779	3,025	2,836	48.9%	46.7%	47.6%	46.4%	-2.2%	0.9%	-1.2%	-2.5%
	Hay/Pasture	333	167	313	148	5.4%	2.8%	4.9%	2.4%	-2.6%	2.1%	-2.5%	-3.0%
	Totals	**3,338**	**2,946**	**3,338**	**2,985**	**54.3%**	**49.5%**	**52.5%**	**48.8%**	**-4.8%**	**3.0%**	**-3.7%**	**-5.5%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.5	1.5	0.7	1.7	2.2	4.1	0.3	0.1	0.1
Max	85.5	62.4	134.8	46.3	58.1	223.0	181.9	68.9	67.6
Average	12.3	9.9	24.5	24.5	27.9	60.5	49.9	11.1	24.0
Sum	209.6	177.5	220.4	293.4	417.8	604.5	349.5	178.3	120.0

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	81.5
Channel to Riparian (acres)	175.1
Riparian Encroachment (acres)	**93.6**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	179.3
1950s Floodplain Mapped as 2011 Channel (Ac)	13.2
Total Recruitment (1950s to 2011)(Ac)	**192.5**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	3.8	112.2	9.6	0.0	**125.6**
Acres/Valley Mile	0.6	18.7	1.6	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	43.41	0.93%	8.10	4.08	6.16	6.40

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
☐	☑	Bigmouth buffalo
☑	☑	Black bullhead
☐	☑	Black crappie
☐	☑	Blue sucker
☐	☑	Bluegill
☑	☑	Brook stickleback
☐	☑	Brown trout
☐	☑	Burbot
☐	☐	Catfish species
☑	☑	Channel catfish
☑	☑	Common carp
☐	☑	Creek chub
☑	☑	Emerald shiner
☑	☑	Fathead minnow
☑	☑	Flathead chub
☑	☑	Freshwater drum
☑	☑	Goldeye
☑	☑	Green sunfish
☐	☑	Lake chub
☐	☑	Largemouth bass
☑	☑	Longnose dace
☑	☑	Longnose sucker
☑	☑	Minnow species
☐	☐	Mottled sculpin
☑	☑	Mountain sucker
☑	☑	Mountain whitefish
☐	☑	Northern pike
☑	☑	Northern plains killifish
☐	☐	Northern redbelly dace
☐	☐	Pallid sturgeon
☑	☑	Pumpkinseed
☐	☐	Rainbow trout
☑	☑	River carpsucker
☐	☑	Rock bass
☑	☑	Sand shiner
☑	☑	Sauger
☑	☑	Shorthead redhorse
☐	☐	Shortnose gar
☐	☑	Shovelnose sturgeon
☐	☐	Sicklefin chub
☑	☑	Smallmouth bass
☑	☑	Smallmouth buffalo
☑	☑	Stonecat
☐	☐	Sturgeon chub
☑	☑	Sucker species
☐	☑	Sunfish species
☑	☑	Walleye
☑	☑	Western silvery minnow
☐	☐	White bass
☑	☑	White crappie
☑	☑	White sucker
☑	☑	Yellow bullhead
☐	☐	Yellow perch

Low Flow Fisheries Habitat Mapping

2001 (Acres)

Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	118.7	58.2	7.7%
Rip Rap Bottom	78.8	48.8	6.5%
Bluff Pool	182.1	138.0	18.3%
Secondary Channel	52.4	28.8	3.8%
Secondary Channel (Seasonal)	56.3	67.3	8.9%
Channel Crossover	142.5	128.8	17.1%
Point Bar		41.3	5.5%
Side Bar		35.9	4.8%
Mid-channel Bar		34.2	4.5%
Island	122.7	131.6	17.5%
Dry Channel		40.6	5.4%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern | Potential Species of Concern

Reach	Region	Species	Reach	Region	Species	Reach	Region	Species	Reach	Region	Species
✓	✓	American Robin		✓	Chipping Sparrow		✓	Killdeer	✓	✓	Song Sparrow
	✓	American Crow		✓	Clay-collared Sparrow		✓	Lark Bunting		✓	Spotted Sandpiper
✓	✓	American Goldfinch	✓	✓	Cliff Swallow	✓	✓	Lark Sparrow	✓	✓	Spotted Towhee
	✓	American Kestrel		✓	Common Grackle	✓	✓	Lazuli Bunting		✓	Sharp-shinned Hawk
✓	✓	American Redstart		✓	Common Merganser	✓	✓	Least Flycatcher		✓	Swainson's Thrush
	✓	Bald Eagle		✓	Common Nighthawk		✓	Mallard		✓	Sandhill Crane
		Baltimore Oriole			Common Raven			Mountain Bluebird	✓	✓	Tree Swallow
	✓	Barn Swallow	✓	✓	Common Yellowthroat	✓	✓	Mourning Dove	✓	✓	Turkey Vulture
✓	✓	Belted Kingfisher		✓	Cooper's Hawk	✓	✓	Northern Flicker		✓	Upland Sandpiper
	✓	Black-billed Cuckoo		✓	Dickcissel		✓	Orchard Oriole		✓	Vesper Sparrow
	✓	Black-billed Magpie	✓	✓	Downy Woodpecker			Osprey		✓	Violet-green Swallow
✓	✓	Black-capped Chickadee		✓	Eastern Bluebird	✓	✓	Ovenbird	✓	✓	Warbling Vireo
	✓	Black-and-white Warbler	✓	✓	Eastern Kingbird		✓	Plumbeous Vireo	✓	✓	Western Kingbird
	✓	Black-headed Grosbeak		✓	Eurasian Collared-dove		✓	Red-headed Woodpecker		✓	Western Meadowlark
✓	✓	Blue Jay	✓	✓	European Starling			Red-naped Sapsucker	✓	✓	Western Wood-pewee
	✓	Bobolink		✓	Field Sparrow	✓	✓	Red Crossbill		✓	White-breasted Nuthatch
	✓	Brewer's Blackbird		✓	Franklin's Gull	✓	✓	Ring-necked Pheasant		✓	White-throated Swift
✓	✓	Brown-headed Cowbird		✓	Grasshopper Sparrow	✓	✓	Red-tailed hawk		✓	Wild Turkey
	✓	Brown Creeper		✓	Gray Catbird		✓	Rock Dove	✓	✓	Wood Duck
	✓	Brown Thrasher		✓	Great Blue Heron		✓	Red-winged Blackbird			Yellow-bellied Sapsucker
✓	✓	Bullock's Oriole		✓	Great Horned Owl	✓	✓	Red-eyed Vireo			Yellow-billed Cuckoo
	✓	Canada Goose		✓	Hairy Woodpecker			Red-breasted Grosbeak	✓	✓	Yellow-breasted Chat
✓	✓	Cedar Waxwing			House Finch	✓	✓	Say's Phoebe			Yellow-headed Blackbird
✓	✓	Chimney Swift	✓	✓	House Wren		✓	Savannah Sparrow	✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Rosebud	**Upstream River Mile**	253.8
Classification	UA: Unconfined anabranching	**Downstream River Mile**	243.1
General Location	Hammond Valley	**Length**	10.70 mi (17.22 km)
General Comments	Hammond Valley		

Narrative Summary

Reach C9 is 10.7 miles long and is located in the Hammond Valley upstream of Forsyth. The Hammond Valley is an unusually wide segment of the Yellowstone River corridor, similar to the Mission Valley near Hysham. These two valleys owe their shape to the presence of the Bearpaw Shale in the valley wall, which is relatively erodible and prone to mass failure. Because the Mission and Hammond Valleys are so wide, the river has developed a complex series of channels and an expansive riparian forest. These reaches are especially rich in terms of aquatic and riparian habitat extent, diversity, and geomorphic complexity. Reach C9 is an Unconfined Anabranching (UA) reach type, which is typically the most complex and dynamic reach type on the river.

Flow alterations in Reach C9 have been driven primarily by changes in flows on the Bighorn River and water use for irrigation. The 2-year discharge, which is an important flow statistic because it approximately defines the channel capacity, has dropped by 14,400 cfs, or 23.5 percent, due to flow alterations on the river. That reduction in flow has been accompanied by a reduction in the bankfull channel area, or channel size, by 209 acres since 1950.

There are over 10,000 feet of rock riprap in Reach C9, as well as 1,100 feet of flow deflectors. This reach experienced severe bank erosion during the 2011 flood when some banks migrated several hundred feet. In response to that erosion, several thousand feet of bank armor were constructed after 2001, mostly on the south side of the river. This riprap represents both new projects and extensions on older projects. Some flow deflectors in the reach were flanked during the flood and now sit in the middle of the river. Other impacts in Reach C9 include almost four miles of side channel that have been blocked by dikes. This loss is due to the blockage of one very long side channel on the north side of the corridor that was clearly active in 1950, but by 1976 was plugged on its upper end.

The combination of bank armoring and reduced energy due to flow alterations has resulted in a reduced floodplain turnover rate in Reach C9 from 22.2 acres per year to 12.9 acres per year. The area of open bar habitat mapped under low flow conditions dropped by almost 100 acres since 1950, reflecting riparian expansion into the channel, reduced sediment recruitment from banks, and reduced sediment loading from the Bighorn River.

Over 40 percent of the land area that was historically inundated by a 5-year flood now remains dry during that frequency event. Most of these isolated areas currently typically flood irrigated fields, some of which were riparian forest in the 1950s. The vast majority of irrigated land in Reach C9 is under flood irrigation (3,900 acres) while 515 acres are under pivot. In the upstream end of the reach, pivots on either side of the river extend into the Channel Migration Zone. About 6 percent of the total CMZ has been restricted by physical features.

There are several animal handling facilities in Reach C9 that are adjacent to the main river channel or smaller side channels, tributaries, or swales. These are located at RM 252L (side channel), RM 248L (tributary), and RM 245R (main channel).

Reach C9 was sampled as part of the avian study. A total of 73 bird species were identified in the reach. Five bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were found, the Black and White Warbler, Dickscissel, Plumbeous Vireo, Ovenbird, and Chimney Swift. Three Species of Concern (SOC) were identified, the Black-billed Cuckoo, Bobolink, and Red-headed Woodpecker. With the expansion of agriculture in the reach, the extent of forest at low risk of cowbird parasitism dropped from 108 acres per valley mile in 1950 to 64 acres per valley mile in 2001.

Reach C9 has 74 acres of mapped Russian olive, which appears to be concentrated on the banks of isolated side channels and sloughs, but also distributed through cottonwood forest in the downstream portion of the reach.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,720 cfs to 3,020 cfs with human development, a reduction of 36 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,150 cfs under unregulated conditions to 3,320 cfs under regulated conditions at Reach C10 downstream where the analysis begins, a reduction of 46 percent.

CEA-related observations in Reach C9 include:
•Reduced floodplain and riparian turnover rates due to flow alterations and bank armoring
•Lost side channel extent due to side channel plugs
•Expansion of Russian olive into abandoned side channels and riparian forest
•5-year floodplain isolation due to agricultural dikes and flow alterations
•Encroachment of pivot irrigation into Channel Migration Zone
•Increased risk of cowbird parasitism with agricultural expansion

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C9 include:
•Side channel reactivation at RM 252L
•Nutrient management associated with animal handling facilities at RM 252L, RM 248L, and RM 245R.

•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	59.1	110.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		61,300	77,300	87,800	111,000	121,000	145,000	4,720	3,846
Regulated		46,900	61,300	70,700	91,600	101,000	122,000	3,020	2,227
% Change		-23.49%	-20.70%	-19.48%	-17.48%	-16.53%	-15.86%	-36.02%	-42.10%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	6/13/96 - 8/11/96 - 8/28/97	B/W		6295000	67900
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/12/2005	color	1-meter pixels	6309000	17500
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	8/11/2009	Color	1-meter pixels	6309000	12900
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2011	NAIP	7/15/2011	Color	1-meter pixels	6309000	58000
2013	NAIP	07/21/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	5,856	5.2%	10,284	9.1%	4,428
	Flow Deflectors	196	0.2%	356	0.3%	160
	Between Flow Deflectors	757	0.7%	757	0.7%	0
	Feature Type Totals	**6,809**	**6.0%**	**11,397**	**10.1%**	**4,587**
Floodplain Control						
	Floodplain Dike/Levee	3,364	3.0%	3,364	3.0%	0
	Feature Type Totals	**3,364**	**3.0%**	**3,364**	**3.0%**	**0**
	Reach Totals	**10,173**	**9.0%**	**14,761**	**13.1%**	**4,587**

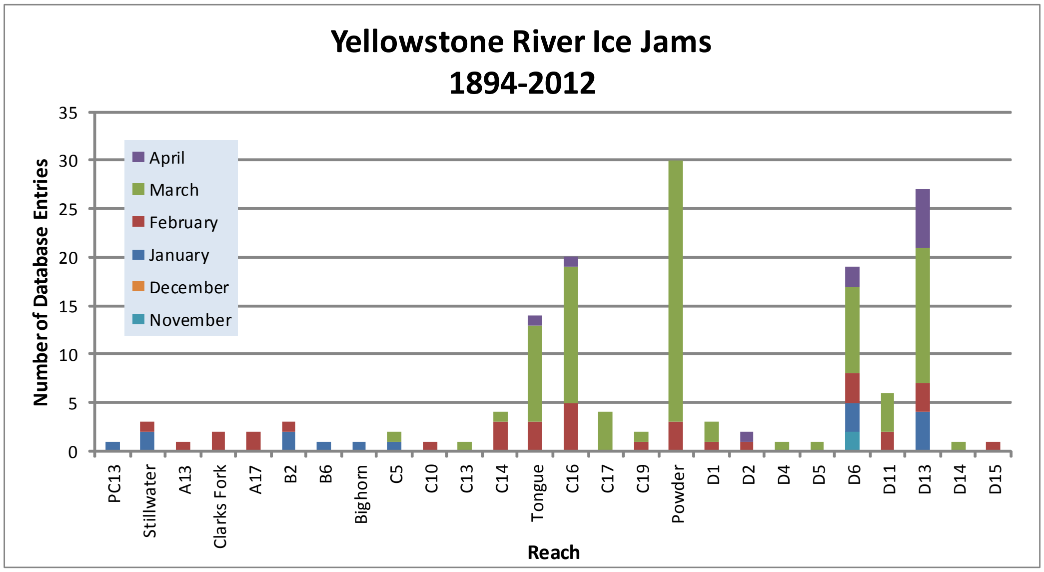
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	951	0	0	0	0	0	0	0
Rock RipRap	4,467	0	1,332	0	0	0	0	0
Totals	**5,419**	**0**	**1,332**	**0**	**0**	**0**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	58,235	84,622	2.45	1950 to 1976:	-0.20%
1976	59,221	85,771	2.45	1976 to 1995:	-16.37%
1995	62,527	65,495	2.05	1995 to 2001:	2.21%
2001	56,479	61,721	2.09	1950 to 2001:	-14.69%
Change 1950 - 2001	**-1,756**	**-22,901**	**-0.36**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	19,348

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	183	2.9%		
Agriculture (generally relates to field boundaries)	13	0.2%		
Agriculture (isloated by canal or large ditch)	24	0.4%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	48	0.8%		
Transportation (Interstate and other roads)	33	0.5%		
Total Not Isolated (Ac)	6020		4103	
Total Floodplain Area (Ac)	6321		6149	
Total Isolated (Ac)	**300**	**4.8%**	**2046**	**42.7%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	377	0	207	**584**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
699	1,398	5,962	333	6%	54	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Other Infrastructure	39	0.6%
	Irrigated	192	3.2%
Flow Deflectors			
	Irrigated	39	0.6%
Dike/Levee			
	Irrigated	63	1.1%
	Totals	**333**	**5.5%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
1005.8	0.0	173.9	0.0	0.7

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	88	266	309	312	0.8%	2.3%	2.7%	2.7%
	Totals	**88**	**266**	**309**	**312**	**0.8%**	**2.3%**	**2.7%**	**2.7%**
Agricultural Land									
	Non-Irrigated	4,126	4,275	4,887	4,445	35.8%	37.1%	42.4%	38.6%
	Irrigated	3,895	3,933	3,879	4,014	33.8%	34.1%	33.7%	34.8%
	Totals	**8,021**	**8,208**	**8,767**	**8,459**	**69.6%**	**71.2%**	**76.1%**	**73.4%**
Channel									
	Channel	3,295	2,913	2,300	2,618	28.6%	25.3%	20.0%	22.7%
	Totals	**3,295**	**2,913**	**2,300**	**2,618**	**28.6%**	**25.3%**	**20.0%**	**22.7%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	12	29	16	0.0%	0.1%	0.3%	0.1%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	1	2	12	12	0.0%	0.0%	0.1%	0.1%
	Totals	**1**	**15**	**41**	**27**	**0.0%**	**0.1%**	**0.4%**	**0.2%**
Transportation									
	Public Road	63	63	63	64	0.5%	0.5%	0.6%	0.6%
	Interstate	0	4	4	4	0.0%	0.0%	0.0%	0.0%
	Railroad	53	53	37	37	0.5%	0.5%	0.3%	0.3%
	Totals	**115**	**119**	**105**	**105**	**1.0%**	**1.0%**	**0.9%**	**0.9%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	131	131	515	0.0%	1.6%	1.5%	6.1%	1.6%	-0.1%	4.6%	6.1%
	Flood	3,895	3,802	3,749	3,499	48.6%	46.3%	42.8%	41.4%	-2.2%	-3.6%	-1.4%	-7.2%
	Totals	**3,895**	**3,933**	**3,879**	**4,014**	**48.6%**	**47.9%**	**44.3%**	**47.4%**	**-0.6%**	**-3.7%**	**3.2%**	**-1.1%**

Non-Irrigated													
	Multi-Use	3,869	4,141	4,651	4,362	48.2%	50.5%	53.1%	51.6%	2.2%	2.6%	-1.5%	3.3%
	Hay/Pasture	257	134	236	83	3.2%	1.6%	2.7%	1.0%	-1.6%	1.1%	-1.7%	-2.2%
	Totals	**4,126**	**4,275**	**4,887**	**4,445**	**51.4%**	**52.1%**	**55.7%**	**52.6%**	**0.6%**	**3.7%**	**-3.2%**	**1.1%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.2	0.4	2.3	0.4	3.1	2.3	6.2	1.7	1.9
Max	102.7	45.6	58.9	428.3	351.0	575.9	132.5	212.8	345.7
Average	12.5	8.9	18.3	60.4	62.7	66.5	32.9	39.4	58.5
Sum	753.0	410.6	474.6	2,173.7	1,881.3	1,995.2	493.4	906.7	876.9

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	540.7
Channel to Riparian (acres)	925.3
Riparian Encroachment (acres)	**384.6**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	933.6
1950s Floodplain Mapped as 2011 Channel (Ac)	354.9
Total Recruitment (1950s to 2011)(Ac)	**1288.5**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	29.2	308.5	244.4	0.0	**582.1**
Acres/Valley Mile	3.8	40.0	31.7	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	74.01	0.73%	3.86	0.78	21.73	20.39

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	485.2	318.5	13.8%
Rip Rap Bottom	49.0	39.4	1.7%
Bluff Pool	35.0	26.9	1.2%
Secondary Channel	12.5	20.4	0.9%
Secondary Channel (Seasonal)	468.3	254.6	11.1%
Channel Crossover	284.0	183.2	8.0%
Point Bar		172.4	7.5%
Side Bar		109.8	4.8%
Mid-channel Bar		53.2	2.3%
Island	965.8	965.8	42.0%
Dry Channel		155.6	6.8%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern

Potential Species of Concern

Reach	Region	
✓	✓	American Robin
✓	✓	American Crow
✓	✓	American Goldfinch
✓	✓	American Kestrel
✓	✓	American Redstart
✓	✓	Bald Eagle
✓	✓	Baltimore Oriole
✓	✓	Barn Swallow
✓	✓	Belted Kingfisher
✓	✓	Black-billed Cuckoo
✓	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
✓	✓	Black-and-white Warbler
✓	✓	Black-headed Grosbeak
✓	✓	Blue Jay
✓	✓	Bobolink
✓	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
	✓	Brown Creeper
✓	✓	Brown Thrasher
✓	✓	Bullock's Oriole
	✓	Canada Goose
✓	✓	Cedar Waxwing
✓	✓	Chimney Swift

Reach	Region	
	✓	Chipping Sparrow
✓	✓	Clay-collared Sparrow
✓	✓	Cliff Swallow
✓	✓	Common Grackle
✓	✓	Common Merganser
	✓	Common Nighthawk
		Common Raven
✓	✓	Common Yellowthroat
✓	✓	Cooper's Hawk
✓	✓	Dickcissel
✓	✓	Downy Woodpecker
✓	✓	Eastern Bluebird
✓	✓	Eastern Kingbird
	✓	Eurasian Collared-dove
✓	✓	European Starling
✓	✓	Field Sparrow
	✓	Franklin's Gull
✓	✓	Grasshopper Sparrow
✓	✓	Gray Catbird
	✓	Great Blue Heron
✓	✓	Great Horned Owl
✓	✓	Hairy Woodpecker
		House Finch
✓	✓	House Wren

Reach	Region	
✓	✓	Killdeer
	✓	Lark Bunting
✓	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
	✓	Mallard
		Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
✓	✓	Orchard Oriole
		Osprey
✓	✓	Ovenbird
✓	✓	Plumbeous Vireo
✓	✓	Red-headed Woodpecker
		Red-naped Sapsucker
✓	✓	Red Crossbill
✓	✓	Ring-necked Pheasant
✓	✓	Red-tailed hawk
✓	✓	Rock Dove
✓	✓	Red-winged Blackbird
✓	✓	Red-eyed Vireo
		Red-breasted Grosbeak
	✓	Say's Phoebe
	✓	Savannah Sparrow

Reach	Region	
✓	✓	Song Sparrow
	✓	Spotted Sandpiper
✓	✓	Spotted Towhee
✓	✓	Sharp-shinned Hawk
✓	✓	Swainson's Thrush
✓	✓	Sandhill Crane
✓	✓	Tree Swallow
	✓	Turkey Vulture
✓	✓	Upland Sandpiper
✓	✓	Vesper Sparrow
✓	✓	Violet-green Swallow
✓	✓	Warbling Vireo
✓	✓	Western Kingbird
✓	✓	Western Meadowlark
✓	✓	Western Wood-pewee
✓	✓	White-breasted Nuthatch
✓	✓	White-throated Swift
✓	✓	Wild Turkey
✓	✓	Wood Duck
		Yellow-bellied Sapsucker
		Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
		Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.

There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County Rosebud

Classification PCM: Partially confined meandering

General Location Forsyth

General Comments Forsyth

Upstream River Mile 243.1

Downstream River Mile 236.3

Length 6.80 mi (10.94 km)

Narrative Summary

Reach C10 is 6.8 miles long and is located at Forsyth. It is a Partially Confined Meandering reach type, as the river flows within a primary meandering thread that is partially confined by the northern bluff line at the Forsyth Bridge.

There is approximately three miles of rock riprap in the reach, 500 feet of which was built since 2001. About a mile of armor is protecting the active rail line on the south side of the river, and another 3,700 feet are protecting the city of Forsyth. Just below Cartersville Dam, a ~330 foot-long stretch of bank armor was flanked sometime between 2001 and 2011. The river has since migrated to the south about 50 feet past the abandoned armor. As of 2011 there were 1,600 feet of flow deflectors mapped in the reach. About 22 percent of the total bankline is armored by either rock riprap or flow deflectors. There is also about a mile of floodplain dikes/levees in the reach, which are located on the south bank at Forsyth.

Cartersville Dam is located at RM 238.5 in the town of Forsyth. This diversion dam was constructed in the early 1930's and consists of a rock rubble riprap core that is capped by concrete. The structure is 800 feet long, spanning the width of the Yellowstone River. The river flows within a single thread at the structure, flowing along the northern bluff line of the Yellowstone River valley. Because of its impacts on the Yellowstone River fishery, efforts have begun to develop suitable alternatives and bypass designs to promote fish passage at Cartersville.

About 20 percent of the total 100-year floodplain has become isolated due to human development. The isolation is due to a combination of floodplain dikes that protect the city of Forsyth and the active railroad. The 5-year floodplain is even more affected; 50 percent of the historic 5-year floodplain is no longer inundated at that frequency. Most of the isolated 5-year floodplain area is occupied by flood irrigated fields north of the river, and by urban development in Forsyth. At RM 238 the river is migrating northward, and has reached the toe of the abandoned Milwaukee Rail Line embankment. Migration through this grade will increase floodplain access on the north side of the river downstream of Cartersville Dam. As this is an urban reach, strategic floodplain reconnection in this area could be beneficial.

One ice jam was reported in Reach C10 in February of 1996. No damages were reported.

Land use is dominated by agriculture (~4,700 acres), with 280 acres of pivot irrigation development since 1950. There are about 850 acres of urban/exurban development in the reach. About 4 percent of the CMZ is restricted by physical features, and most of that area is in town.

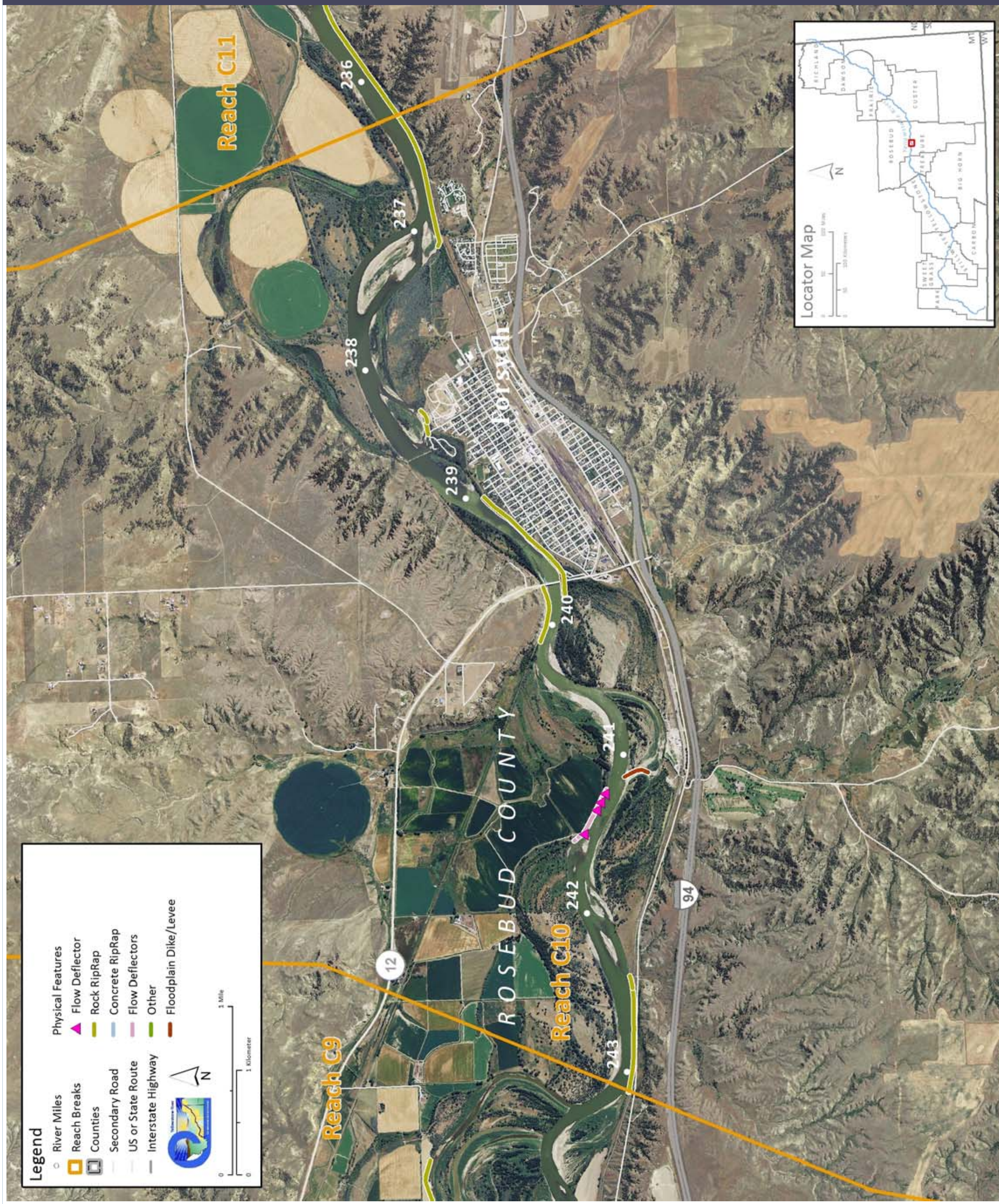
There are 250 acres of Russian olive in the reach, most of which is dispersed in riparian areas. Russian olive densities are especially high downstream of Cartersville Diversion dam on the south bank of the river near the water treatment plant.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,730 cfs to 3,020 cfs with human development, a reduction of 36 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,150 cfs under unregulated conditions to 3,320 cfs under regulated conditions, a reduction of 46 percent.

CEA-Related observations in Reach C10 include:
•Floodplain isolation due to urban/exurban development.
•Extensive Russian olive colonization in urbanized reach

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C10 include:
•Floodplain reconnection at RM 238L behind abandoned Milwaukee rail line.
•Diversion structure management at Cartersville Dam
•Watercraft passage at Cartersville Dam
•Fish Passage at Cartersville Dam
•Flanked bank armor removal at RM 238.4R
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	52.3	121.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		61,300	77,300	87,900	111,000	121,000	145,000	4,730	6,150
Regulated		46,900	61,300	70,700	91,600	101,000	122,000	3,020	3,320
% Change		-23.49%	-20.70%	-19.57%	-17.48%	-16.53%	-15.86%	-36.15%	-46.02%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Season		5%	50%	95%
Spring	Unregulated	60,000	22,400	5,930
	Regulated	46,500	13,600	4,330
	% Change	**-23%**	**-39%**	**-27%**
Summer	Unregulated	42,100	13,200	6,150
	Regulated	32,200	8,230	3,320
	% Change	**-24%**	**-38%**	**-46%**
Fall	Unregulated	9,030	5,460	2,280
	Regulated	10,400	6,800	3,590
	% Change	**15%**	**25%**	**57%**
Winter	Unregulated	11,400	4,850	1,990
	Regulated	12,000	5,940	3,230
	% Change	**5%**	**22%**	**62%**
Annual	Unregulated	44,900	7,770	2,760
	Regulated	33,800	7,280	3,580
	% Change	**-25%**	**-6%**	**30%**

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	11-Aug-96	B/W		6295000	7650
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/12/2005	color	1-meter pixels	6309000	17500
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	8/11/2009	Color	1-meter pixels	6309000	12900
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/15/2011	Color	1-meter pixels	6309000	58000
2013	NAIP	07/21/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	13,814	19.2%	14,306	19.8%	493
	Flow Deflectors	607	0.8%	345	0.5%	-262
	Between Flow Deflectors	1,302	1.8%	1,302	1.8%	0
	Feature Type Totals	**15,723**	**21.8%**	**15,954**	**22.1%**	**231**
Floodplain Control						
	Floodplain Dike/Levee	4,861	6.7%	4,071	5.6%	-790
	Feature Type Totals	**4,861**	**6.7%**	**4,071**	**5.6%**	**-790**
	Reach Totals	**20,584**	**28.6%**	**20,025**	**27.8%**	**-559**

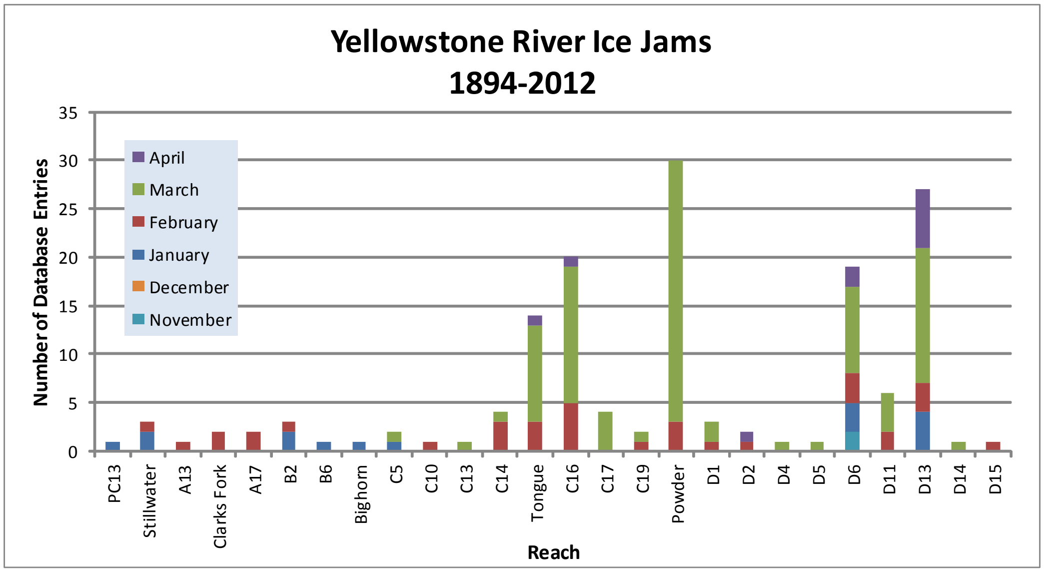
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	1,725	0	0	0	0	0	0	0
Rock RipRap	0	0	0	722	0	5,054	3,720	0
Totals	**1,725**	**0**	**0**	**722**	**0**	**5,054**	**3,720**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
2/7/1996	Break-up	239	?

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	37,786	9,048	1.24
1976	35,535	9,945	1.28
1995	36,024	13,064	1.36
2001	36,044	15,719	1.44
Change 1950 - 2001	**-1,742**	**6,671**	**0.20**

	% Change in Braiding
1950 to 1976:	3.26%
1976 to 1995:	6.47%
1995 to 2001:	5.39%
1950 to 2001:	15.87%

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	44	1.4%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	338	10.8%		
Railroad	223	7.1%		
Abandoned Railroad	16	0.5%		
Transportation (Interstate and other roads)	15	0.5%		
Total Not Isolated (Ac)	2507		1753	
Total Floodplain Area (Ac)	3143		2872	
Total Isolated (Ac)	**636**	**20.2%**	**1119**	**49.9%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	29	0	21	**50**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
210	420	1,344	67	5%	501	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Irrigated	19	1.0%
RipRap			
	Urban Residential	11	0.6%
Dike/Levee			
	Urban Residential	43	2.3%
	Totals	**73**	**3.9%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
39.4	0.0	2.5	70.8	1.6

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	29	72	101	104	0.4%	1.1%	1.5%	1.5%
	Totals	**29**	**72**	**101**	**104**	**0.4%**	**1.1%**	**1.5%**	**1.5%**
Agricultural Land									
	Non-Irrigated	4,488	3,771	3,602	3,565	67.0%	56.3%	53.8%	53.2%
	Irrigated	904	1,138	1,166	1,152	13.5%	17.0%	17.4%	17.2%
	Totals	**5,392**	**4,909**	**4,768**	**4,717**	**80.5%**	**73.3%**	**71.2%**	**70.4%**
Channel									
	Channel	684	736	706	758	10.2%	11.0%	10.5%	11.3%
	Totals	**684**	**736**	**706**	**758**	**10.2%**	**11.0%**	**10.5%**	**11.3%**
ExUrban									
	ExUrban Other	0	26	26	26	0.0%	0.4%	0.4%	0.4%
	ExUrban Undeveloped	0	0	21	0	0.0%	0.0%	0.3%	0.0%
	ExUrban Industrial	0	18	18	18	0.0%	0.3%	0.3%	0.3%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	1	76	97	0.0%	0.0%	1.1%	1.5%
	Totals	**0**	**45**	**142**	**142**	**0.0%**	**0.7%**	**2.1%**	**2.1%**
Transportation									
	Public Road	36	56	57	57	0.5%	0.8%	0.9%	0.9%
	Interstate	0	153	153	153	0.0%	2.3%	2.3%	2.3%
	Railroad	72	72	37	37	1.1%	1.1%	0.6%	0.6%
	Totals	**107**	**281**	**248**	**248**	**1.6%**	**4.2%**	**3.7%**	**3.7%**
Urban									
	Urban Other	102	70	106	102	1.5%	1.0%	1.6%	1.5%
	Urban Residential	270	365	390	390	4.0%	5.5%	5.8%	5.8%
	Urban Commercial	41	80	97	97	0.6%	1.2%	1.4%	1.4%
	Urban Undeveloped	66	44	41	41	1.0%	0.7%	0.6%	0.6%
	Urban Industrial	4	93	97	97	0.1%	1.4%	1.4%	1.5%
	Totals	**484**	**652**	**732**	**728**	**7.2%**	**9.7%**	**10.9%**	**10.9%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	206	263	278	0.0%	4.2%	5.5%	5.9%	4.2%	1.3%	0.4%	5.9%
	Flood	904	932	904	874	16.8%	19.0%	18.9%	18.5%	2.2%	0.0%	-0.4%	1.8%
	Totals	**904**	**1,138**	**1,166**	**1,152**	**16.8%**	**23.2%**	**24.5%**	**24.4%**	**6.4%**	**1.3%**	**0.0%**	**7.7%**

Non-Irrigated												
Multi-Use	4,015	3,577	3,585	3,557	74.4%	72.9%	75.2%	75.4%	-1.6%	2.3%	0.2%	1.0%
Hay/Pasture	474	194	17	8	8.8%	4.0%	0.4%	0.2%	-4.8%	-3.6%	-0.2%	-8.6%
Totals	**4,488**	**3,771**	**3,602**	**3,565**	**83.2%**	**76.8%**	**75.5%**	**75.6%**	**-6.4%**	**-1.3%**	**0.0%**	**-7.7%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.4	1.9	0.9	0.9	1.7	2.4	5.6	3.6	18.3
Max	294.3	241.2	171.7	241.2	281.1	163.9	232.9	115.9	116.4
Average	36.5	33.0	27.6	49.1	58.3	33.1	54.4	29.7	76.1
Sum	474.5	296.9	386.5	736.7	815.9	694.5	435.0	267.4	380.3

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	87.1
Channel to Riparian (acres)	119.1
Riparian Encroachment (acres)	**32.0**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	128.0
1950s Floodplain Mapped as 2011 Channel (Ac)	12.3
Total Recruitment (1950s to 2011)(Ac)	**140.3**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	11.6	89.6	30.1	0.0	**131.2**
Acres/Valley Mile	1.9	14.8	5.0	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	250.55	5.68%	6.77	2.27	15.11	1.46

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	180.9	105.4	14.9%
Rip Rap Bottom	31.5	21.8	3.1%
Rip Rap Margin	122.2	100.7	14.3%
Secondary Channel	28.5	22.9	3.2%
Secondary Channel (Seasonal)	71.5	41.6	5.9%
Channel Crossover	110.0	102.7	14.5%
Point Bar		55.3	7.8%
Side Bar		14.8	2.1%
Mid-channel Bar		28.2	4.0%
Island	76.1	76.1	10.8%
Dry Channel		51.4	7.3%
Dam Influenced	85.2	85.1	12.1%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Rosebud	**Upstream River Mile**	236.3
Classification	PCM/I: Partially confined meandering/islands	**Downstream River Mile**	225
General Location	Forsyth to Cartersville Bridge	**Length**	11.30 mi (18.19 km)

General Comments Reach C11 is located upstream of Cartersiville Bridge and provides a good example of extensive floodplain encroachments on both sides of the river due to both active and abandoned rail lines, as well as side channel loss due to diking.

Narrative Summary

Reach C11 is located in Rosebud County, just downstream from the community of Forsyth. The reach is an 11.3 mile long Partially Confined Meandering channel type, extending from RM 225.0 to RM 236.3. The partial confinement is imposed by bedrock bluffs south of the river. The floodplain area north of the river has become isolated by about 9 miles of abandoned railroad grade. Rosebud Creek enters the Yellowstone River in the lowermost end of the reach from the south, and Little Porcupine Creek and Horse Creek flow in from the north. The Far West fishing access is located on the north bank at the downstream end of the reach. Reach C11 is relatively dynamic with most erosion and bank migration occurring on the downstream limbs of major meanders.

In Reach C11, the river commonly runs along the southern bluff line that is made up of Cretaceous age Lance Formation and Hell Creek Formation. The BNSF line follows this edge of the valley, and as a result much of the bluff line is armored. According to Womack (2001), the Hell Creek Formation in this area consists of resistant cemented sandstone that forms a 12 foot cap over claystone, which is subject to small slumps on the very steep slope below the rail line, thus driving the need for bank armor. Bank migration is also very active in the reach; at RM 229 for example, the river has migrated almost 700 feet southward since 1950 and is now within 100 feet of the rail line.

As of 2011 there were over 4.5 miles of bank armor protecting about 20 percent of the total bankline in Reach C11, and almost all of that armor is rock riprap protection against the active rail line. Since 2001, about 1,500 feet of flow deflectors have been built in the reach as well to protect irrigated fields on the north bank. Physical features mapping indicates the loss of 500 feet of car bodies between 2001 and 2011 at RM 230.1L where the bank has eroded behind the car bodies which are now up to 70 feet out in the river. A ~500 foot-long stretch of rock riprap on the north side of the river at RM 226.6R is currently protecting flood irrigated land, but is becoming flanked on its upstream end.

Reach C11 has seen major losses of side channels due to small floodplain dikes. Since 1950, 4.3 miles of side channel have been blocked. Three major side channels have dikes blocking them; at RM 232R across from the mouth of Porcupine Creek, at RM 230L below the mouth of Horse Creek, and at RM 229R. All of these channels appear to have good potential for reactivation. There are other older dikes that block swales that could also be potentially reactivated (e.g. RM 234R).

Similar to other reaches downstream of the Bighorn River confluence, the river channel has become smaller in Reach C11 since 1950. In 2001, the bankfull footprint was about 130 acres smaller than it was in 1950, and riparian mapping shows over 200 acres of riparian encroachment into old channel areas. Floodplain turnover rates are also lower; from 1950-1975 the average annual rate of floodplain turnover was 9.3 acres per year, and since 1975 it has been 6.4 acres per year.

On the north side of the river, the abandoned Milwaukee rail line isolates extensive historic floodplain area. At the 100 year event, 767 acres of contiguous area is isolated by the old rail line embankment, accounting for 17 percent of the mapped 100-year floodplain area. Just upstream of the mouth of Horse Creek, however, the river has migrated through the embankment. That erosion through the embankment will continue as the river is actively flanking rock riprap at the mouth of Horse Creek. The active BNSF line also isolates pockets of historic floodplain on the south side of the river.

A total of 328 acres of land that would normally be in the river’s natural Channel Migration Zone (CMZ) have become restricted by physical features, which represents about 9 percent of the total CMZ area.

Land uses in Reach C11 are predominantly agricultural, with some conversion from flood irrigation to pivot since 1950. As of 2011 there were about 450 acres under pivot irrigation in the reach, and 76 of those acres are within the 5-year floodplain. Pivot irrigation has also encroached into the CMZ; about 65 acres that were developed for pivot are within the CMZ footprint. This area under pivot is at RM 227.5R, where a large pivot field has been developed in the core of a major meander. Irrigation development included riparian clearing; between 1950 and 2011 about 124 acres of riparian area was cleared for irrigation, which is 8 percent of the total 1950s riparian area.

Reach C11 hosts a relatively dense concentration of wetlands; there are almost 40 acres of wetland per valley mile in the reach, most of which is emergent marshes and wet meadows. There are also 183 acres of mapped Russian olive in the reach, which is distributed throughout the riparian zone and locally concentrated in blocked side channels.

Reach C11 was sampled as part of the fisheries study. A total of 27 species were sampled in the reach, including Sauger and Blue Sucker, both of which have been identified as Species of Concern by the Montana Natural Heritage Program.

Reach C11 was also sampled as part of the avian study. A total of 42 bird species were identified in the reach, including three Species of Concern: The Chimney Swift, Ovenbird, and Plumbeous Vireo. Reach C11 has seen a reduction in the extent of riparian forest considered at low risk of cowbird parasitism. In 1950, there were 31.3 acres of such forest per valley mile, and by 2001 that forest extent had dropped to 19.8 acres per valley mile.

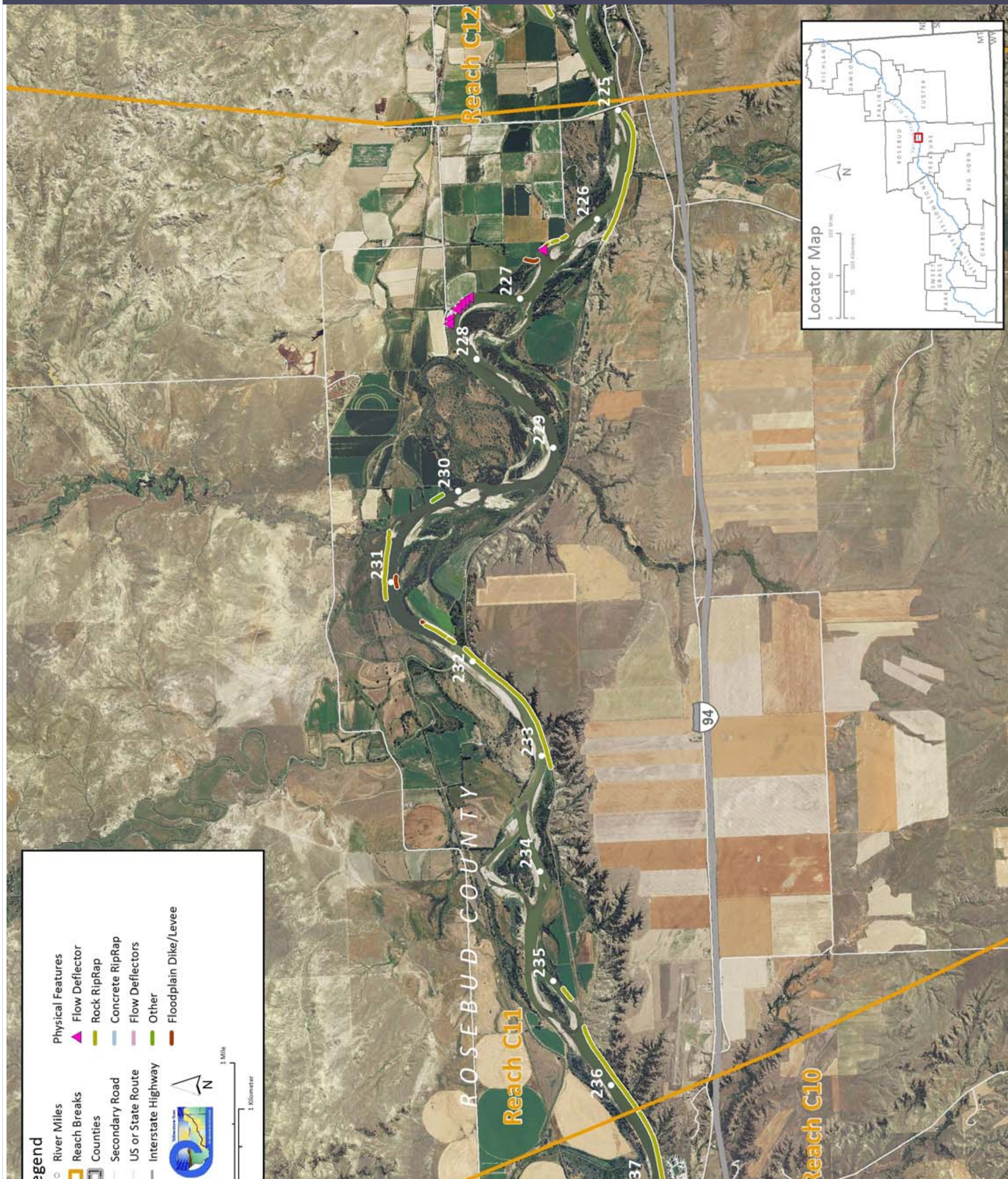
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,820 cfs to 3,060 cfs with human development, a reduction of 37 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,300 cfs under unregulated conditions to 3,370 cfs under regulated conditions, a reduction of 47 percent.

Fall and winter base flows have increased in Reach C11 by about 60 percent.

CEA-Related observations in Reach C11 include:
•Extensive floodplain isolation by the abandoned Milwaukee rail line on the north bank.
•Extensive blocking of side channels
•A regionally high extent of Russian olive possibly associated with the loss of side channels.
•Extensive armoring with CMZ encroachment
•Flanking of car bodies
•Active flanking of riprap

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C11 include:
•Removal of car bodies in river at RM 230.1L
•Side channel reactivation at RM 232R, RM 230L, and RM 229 R.
•Floodplain reconnection behind abandoned railroad grade RM 231L
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	41.0	128.1

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		61,800	77,700	88,000	111,000	120,000	143,000	4,820	6,300
Regulated		47,200	61,600	70,900	90,700	99,000	118,000	3,060	3,370
% Change		-23.62%	-20.72%	-19.43%	-18.29%	-17.50%	-17.48%	-36.51%	-46.51%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	60,500	22,600	6,060
	Regulated	46,800	13,700	4,410
	% Change	**-23%**	**-39%**	**-27%**
Summer	Unregulated	42,600	13,400	6,300
	Regulated	32,500	8,310	3,370
	% Change	**-24%**	**-38%**	**-47%**
Fall	Unregulated	9,120	5,530	2,300
	Regulated	10,500	6,880	3,630
	% Change	**15%**	**24%**	**58%**
Winter	Unregulated	11,700	4,930	2,010
	Regulated	12,300	6,020	3,260
	% Change	**5%**	**22%**	**62%**
Annual	Unregulated	45,400	7,900	2,790
	Regulated	34,100	7,370	3,620
	% Change	**-25%**	**-7%**	**30%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	8/11/1996 - 8/7/96	B/W		6295000	7650
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/29/2005	color	1-meter pixels	6309000	7070
2005	NAIP	07/12/2005	color	1-meter pixels	6309000	17500
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	8/11/2009	Color	1-meter pixels	6309000	12900
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/15/2011	Color	1-meter pixels	6309000	58000
2013	NAIP	07/21/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	21,792	18.2%	22,608	18.8%	816
	Flow Deflectors	0	0.0%	239	0.2%	239
	Car Bodies	504	0.4%	0	0.0%	-504
	Between Flow Deflectors	0	0.0%	1,273	1.1%	1,273
	Feature Type Totals	**22,296**	**18.6%**	**24,119**	**20.1%**	**1,823**
Floodplain Control						
	Transportation Encroachment	10,162	8.5%	10,162	8.5%	0
	Floodplain Dike/Levee	2,700	2.3%	2,700	2.3%	0
	Feature Type Totals	**12,861**	**10.7%**	**12,861**	**10.7%**	**0**
	Reach Totals	**35,157**	**29.3%**	**36,981**	**30.8%**	**1,823**

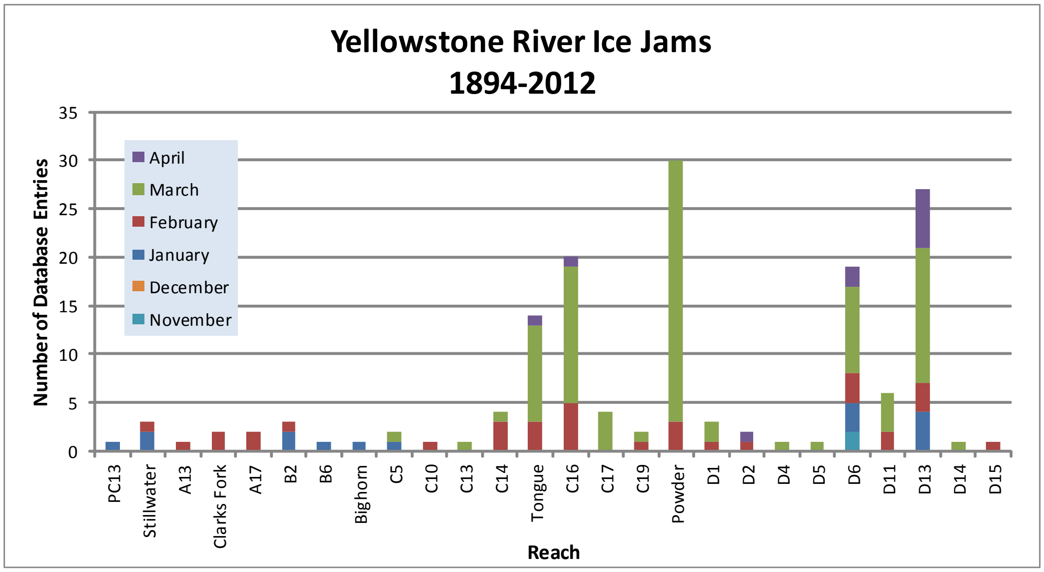
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Car Bodies	505	0	0	0	0	0	0	0
Rock RipRap	2,257	0	0	0	0	23,898	0	0
Totals	**2,762**	**0**	**0**	**0**	**0**	**23,898**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	60,103	72,434	2.21	1950 to 1976:	-14.95%
1976	60,623	53,080	1.88	1976 to 1995:	-15.72%
1995	61,684	35,828	1.58	1995 to 2001:	5.18%
2001	59,992	39,762	1.66	1950 to 2001:	-24.60%
Change 1950 - 2001	**-110**	**-32,672**	**-0.54**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	22,745

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	217	4.8%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	24	0.5%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	115	2.5%		
Abandoned Railroad	767	16.9%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	3415		2422	
Total Floodplain Area (Ac)	4539		3711	
Total Isolated (Ac)	**1124**	**24.8%**	**1290**	**51.2%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	149	0	76	**224**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
330	661	3,371	327	10%	173	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	17	0.5%
RipRap			
	Railroad	184	5.2%
	Irrigated	104	2.9%
Dike/Levee			
	Railroad	24	0.7%
	Totals	**328**	**9.3%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
408.7	0.0	65.3	0.0	19.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	68	108	99	87	0.6%	1.0%	0.9%	0.8%
	Totals	**68**	**108**	**99**	**87**	**0.6%**	**1.0%**	**0.9%**	**0.8%**
Agricultural Land									
	Non-Irrigated	4,989	5,181	5,744	5,630	47.6%	49.5%	54.9%	53.8%
	Irrigated	3,056	3,066	3,038	3,107	29.2%	29.3%	29.0%	29.7%
	Totals	**8,046**	**8,247**	**8,782**	**8,738**	**76.8%**	**78.8%**	**83.9%**	**83.4%**
Channel									
	Channel	2,208	1,949	1,466	1,522	21.1%	18.6%	14.0%	14.5%
	Totals	**2,208**	**1,949**	**1,466**	**1,522**	**21.1%**	**18.6%**	**14.0%**	**14.5%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	50	51	51	51	0.5%	0.5%	0.5%	0.5%
	Interstate	0	17	17	17	0.0%	0.2%	0.2%	0.2%
	Railroad	99	98	56	56	0.9%	0.9%	0.5%	0.5%
	Totals	**149**	**166**	**124**	**124**	**1.4%**	**1.6%**	**1.2%**	**1.2%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	2	2	2	2	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**2**	**2**	**2**	**2**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	95	451	0.0%	0.0%	1.1%	5.2%	0.0%	1.1%	4.1%	5.2%
	Flood	3,056	3,066	2,943	2,656	38.0%	37.2%	33.5%	30.4%	-0.8%	-3.7%	-3.1%	-7.6%
	Totals	**3,056**	**3,066**	**3,038**	**3,107**	**38.0%**	**37.2%**	**34.6%**	**35.6%**	**-0.8%**	**-2.6%**	**1.0%**	**-2.4%**

Non-Irrigated												
Multi-Use	4,564	4,741	5,347	5,247	56.7%	57.5%	60.9%	60.0%	0.8%	3.4%	-0.8%	3.3%
Hay/Pasture	425	440	398	383	5.3%	5.3%	4.5%	4.4%	0.1%	-0.8%	-0.1%	-0.9%
Totals	**4,989**	**5,181**	**5,744**	**5,630**	**62.0%**	**62.8%**	**65.4%**	**64.4%**	**0.8%**	**2.6%**	**-1.0%**	**2.4%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.1	0.6	0.4	0.5	0.6	1.4	1.6	3.2	1.7
Max	65.1	55.0	37.9	349.3	271.1	152.5	140.3	137.5	290.3
Average	7.9	12.5	12.5	35.9	25.9	32.0	24.1	34.9	64.9
Sum	291.9	350.0	237.2	1,076.0	827.3	895.5	384.8	313.7	649.4

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	215.0
Channel to Riparian (acres)	426.6
Riparian Encroachment (acres)	**211.6**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	438.3
1950s Floodplain Mapped as 2011 Channel (Ac)	56.3
Total Recruitment (1950s to 2011)(Ac)	**494.6**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	51.2	230.5	75.1	0.0	**356.8**
Acres/Valley Mile	5.8	26.1	8.5	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	182.60	2.27%	15.11	2.72	51.43	55.53

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
	✓	Bigmouth buffalo
	✓	Black bullhead
✓	✓	Black crappie
✓	✓	Blue sucker
	✓	Bluegill
✓	✓	Brook stickleback
	✓	Brown trout
✓	✓	Burbot
		Catfish species
✓	✓	Channel catfish
✓	✓	Common carp
	✓	Creek chub
✓	✓	Emerald shiner
✓	✓	Fathead minnow
✓	✓	Flathead chub
	✓	Freshwater drum
✓	✓	Goldeye
✓	✓	Green sunfish
	✓	Lake chub
	✓	Largemouth bass
✓	✓	Longnose dace
✓	✓	Longnose sucker
	✓	Minnow species
		Mottled sculpin
✓	✓	Mountain sucker
	✓	Mountain whitefish
	✓	Northern pike
✓	✓	Northern plains killifish
		Northern redbelly dace
		Pallid sturgeon
	✓	Pumpkinseed
		Rainbow trout
✓	✓	River carpsucker
	✓	Rock bass
✓	✓	Sand shiner
✓	✓	Sauger
✓	✓	Shorthead redhorse
		Shortnose gar
✓	✓	Shovelnose sturgeon
		Sicklefin chub
✓	✓	Smallmouth bass
✓	✓	Smallmouth buffalo
✓	✓	Stonecat
		Sturgeon chub
✓	✓	Sucker species
	✓	Sunfish species
✓	✓	Walleye
✓	✓	Western silvery minnow
		White bass
	✓	White crappie
✓	✓	White sucker
	✓	Yellow bullhead
		Yellow perch

Low Flow Fisheries Habitat Mapping

Habitat	Bankfull (2001 Acres)	Low Flow (2001 Acres)	% of Low Flow
Scour Pool	327.8	205.2	14.0%
Rip Rap Bottom	201.6	131.1	8.9%
Rip Rap Margin	141.8	96.6	6.6%
Terrace Pool	11.4	6.8	0.5%
Secondary Channel	110.7	123.3	8.4%
Secondary Channel (Seasonal)	104.6	125.2	8.5%
Channel Crossover	292.4	207.2	14.1%
Point Bar		80.4	5.5%
Side Bar		73.3	5.0%
Mid-channel Bar		100.9	6.9%
Island	275.5	215.9	14.7%
Dry Channel		99.8	6.8%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern Potential Species of Concern

Reach	Region	Species
	✓	American Robin
	✓	American Crow
✓	✓	American Goldfinch
	✓	American Kestrel
✓	✓	American Redstart
	✓	Bald Eagle
		Baltimore Oriole
	✓	Barn Swallow
	✓	Belted Kingfisher
	✓	Black-billed Cuckoo
	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
	✓	Black-and-white Warbler
✓	✓	Black-headed Grosbeak
✓	✓	Blue Jay
	✓	Bobolink
	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
	✓	Brown Creeper
✓	✓	Brown Thrasher
✓	✓	Bullock's Oriole
	✓	Canada Goose
	✓	Cedar Waxwing
✓	✓	Chimney Swift
	✓	Chipping Sparrow
	✓	Clay-collared Sparrow
✓	✓	Cliff Swallow
✓	✓	Common Grackle
	✓	Common Merganser
	✓	Common Nighthawk
		Common Raven
✓	✓	Common Yellowthroat
	✓	Cooper's Hawk
	✓	Dickcissel
✓	✓	Downy Woodpecker
	✓	Eastern Bluebird
✓	✓	Eastern Kingbird
	✓	Eurasian Collared-dove
✓	✓	European Starling
	✓	Field Sparrow
	✓	Franklin's Gull
	✓	Grasshopper Sparrow
✓	✓	Gray Catbird
✓	✓	Great Blue Heron
	✓	Great Horned Owl
✓	✓	Hairy Woodpecker
		House Finch
✓	✓	House Wren
	✓	Killdeer
✓	✓	Lark Bunting
✓	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
✓	✓	Mallard
		Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
	✓	Orchard Oriole
		Osprey
✓	✓	Ovenbird
✓	✓	Plumbeous Vireo
	✓	Red-headed Woodpecker
		Red-naped Sapsucker
	✓	Red Crossbill
✓	✓	Ring-necked Pheasant
	✓	Red-tailed hawk
	✓	Rock Dove
✓	✓	Red-winged Blackbird
✓	✓	Red-eyed Vireo
		Red-breasted Grosbeak
	✓	Say's Phoebe
	✓	Savannah Sparrow
✓	✓	Song Sparrow
	✓	Spotted Sandpiper
✓	✓	Spotted Towhee
	✓	Sharp-shinned Hawk
	✓	Swainson's Thrush
	✓	Sandhill Crane
✓	✓	Tree Swallow
	✓	Turkey Vulture
	✓	Upland Sandpiper
	✓	Vesper Sparrow
	✓	Violet-green Swallow
✓	✓	Warbling Vireo
✓	✓	Western Kingbird
✓	✓	Western Meadowlark
✓	✓	Western Wood-pewee
✓	✓	White-breasted Nuthatch
	✓	White-throated Swift
	✓	Wild Turkey
✓	✓	Wood Duck
		Yellow-bellied Sapsucker
		Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
		Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

Yellowstone River Reach Narratives

Reach C12

County	Rosebud	**Upstream River Mile**	225
Classification	PCM/I: Partially confined meandering/islands	**Downstream River Mile**	214.8
General Location	Rosebud	**Length**	10.20 mi (16.42 km)
General Comments	Rosebud; numerous meander cutoffs		

Narrative Summary

Reach C12 is 10.2 miles long and extends from the Rosebud Bridge at RM 225 downstream to RM 215. The reach classified as Partially Confined Meandering with Islands (PCM/I), indicating some influence of the valley wall, a main meandering channel thread, and numerous meander cutoffs that have generated large islands. The reach is relatively dynamic; at RM 221.5 for example the river has migrated over 900 feet to the northwest since 1950. At RM 217.2R, the river migrated over 300 feet between 2001 and 2011. Most of the rapid migration is on the outer edges (apices) and downstream limbs of large meanders.

As of 2011 there were 4,700 feet of bank armor protecting about 4 percent of the total bankline in Reach C12, and almost all of that armor is rock riprap. About one half of the armor was built between 2001 and 2011. One short section (200 feet) of flow deflectors was also built between 2001 and 2011. The bank armor is protecting agricultural land and the active rail line. Almost 2,000 feet of the mapped bank armor is north of the town of Rosebud on a channel that has been largely abandoned. This channel abandonment has focused flows in the south channel, which currently flows against the town of Rosebud which has minimal erosion protection.

Prior to 1950, about ½ miles of side channel in Reach C12 were blocked. One short channel is just upstream of the town of Rosebud, and a much longer channel is on the south side of the river at RM 219R.

Similar to other reaches downstream of the Bighorn River confluence, the river channel has become smaller in Reach C12 since 1950. In 1950, the bankfull footprint was about 56 acres larger than it was in 2001, and riparian mapping shows over 211 acres of riparian encroachment into old channel areas. Some of that encroachment has been onto mid-channel bars; there was a net loss of 36 acres of open bars since 1950. Floodplain turnover rates are also lower; from 1950-1975 the average annual rate of floodplain turnover was 8.9 acres per year, and since 1975 it has been 5.8 acres per year.

Over a thousand acres of the 100-year floodplain has become isolated from the river, most of which is north of the abandoned rail line. Several pockets of historic 100-year floodplain have also been isolated on the south side of the river between the rail line and bluff area. In total, 29 percent of the entire historic 100-year floodplain has become isolated. Isolation of the 5-year floodplain has been even more substantial; 1,340 acres or 47 percent of the 5-year floodplain has become isolated at that event. Much of this isolated 5-year floodplain is on flood irrigated fields north of the river.

A total of 216 acres of land that would normally be in the river's natural Channel Migration Zone (CMZ) have become restricted by physical features, which represents about 6 percent of the total CMZ area. At Rosebud, 59 acres of urban/exurban land has been mapped within the CMZ.

Land uses in Reach C12 are predominantly agricultural, with some conversion from flood irrigation to pivot since 1950. As of 2011 there were about 430 acres under pivot irrigation in the reach, and 197 of those acres are within the 5-year floodplain. Pivot irrigation has also encroached into the CMZ; about 200 acres that were developed for pivot are within the CMZ footprint. Irrigation development largely occurred prior to 1950, but additional development since then has included riparian clearing; between 1950 and 2011 about 45 acres of riparian area was cleared for irrigation, which is 5 percent of the total 1950s riparian area.

One animal handling facility was mapped at RM 222L that extends to the river bank.

There are 206 acres of mapped Russian olive in the reach, which is distributed throughout the riparian zone.

Reach C12 was sampled as part of the fisheries study. A total of 37 species were sampled in the reach, including Sauger and Blue Sucker, both of which have been identified as Species of Concern by the Montana Natural Heritage Program.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped by 17 percent and the 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,830 cfs to 3,060 cfs with human development, a reduction of 37 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,310 cfs under unregulated conditions to 3,380 cfs under regulated conditions, a reduction of 46 percent.

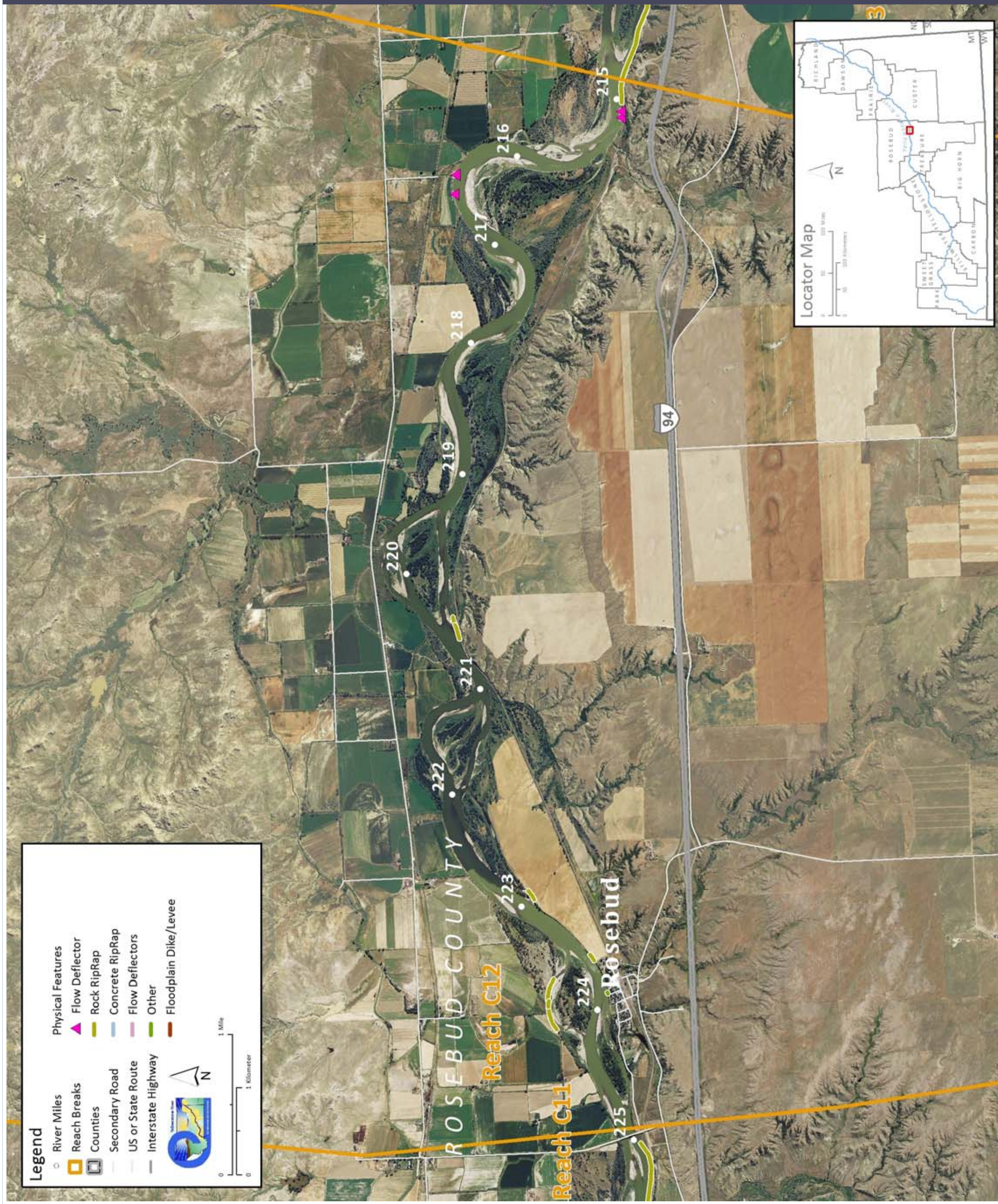
Fall and winter base flows have increased in Reach C12 by about 60 percent.

CEA-Related observations in Reach C12 include:
•Extensive floodplain isolation by the abandoned Milwaukee rail line on the north bank.
•Blocking of side channels

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C12 include:
•Side channel reactivation at RM 219 R.
•Floodplain reconnection behind abandoned railroad grade RM 220L

•Nutrient management at Animal Handling Facility at RM 222L
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	30.8	139.4

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		61,900	77,800	88,100	111,000	120,000	143,000	4,830	6,310
Regulated		47,300	61,700	70,900	90,600	98,900	118,000	3,060	3,380
% Change		-23.59%	-20.69%	-19.52%	-18.38%	-17.58%	-17.48%	-36.65%	-46.43%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	60,500	22,600	6,070
	Regulated	46,900	13,700	4,410
	% Change	**-22%**	**-39%**	**-27%**
Summer	Unregulated	42,700	13,400	6,310
	Regulated	32,500	8,320	3,380
	% Change	**-24%**	**-38%**	**-46%**
Fall	Unregulated	9,130	5,540	2,300
	Regulated	10,500	6,880	3,630
	% Change	**15%**	**24%**	**58%**
Winter	Unregulated	11,700	4,940	2,010
	Regulated	12,300	6,020	3,260
	% Change	**5%**	**22%**	**62%**
Annual	Unregulated	45,400	7,910	2,790
	Regulated	34,100	7,380	3,620
	% Change	**-25%**	**-7%**	**30%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	7/12/96 - 9/11/96 - 8/7/96	B/W		6295000	27600
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/29/2005	color	1-meter pixels	6309000	7070
2005	NAIP	07/08/2005	color	1-meter pixels	6309000	18800
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	8/11/2009	Color	1-meter pixels	6309000	12900
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2009	NAIP	7/15/2009	Color	1-meter pixels	6309000	26400
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/15/2011	Color	1-meter pixels	6309000	58000
2013	NAIP	07/21/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	2,677	2.5%	4,510	4.2%	1,833
	Flow Deflectors	0	0.0%	192	0.2%	192
	Car Bodies	46	0.0%	46	0.0%	0
	Feature Type Totals	**2,723**	**2.6%**	**4,748**	**4.5%**	**2,025**
Floodplain Control						
	Transportation Encroachment	21,018	19.8%	21,018	19.8%	0
	Feature Type Totals	**21,018**	**19.8%**	**21,018**	**19.8%**	**0**
	Reach Totals	**23,740**	**22.3%**	**25,765**	**24.2%**	**2,025**

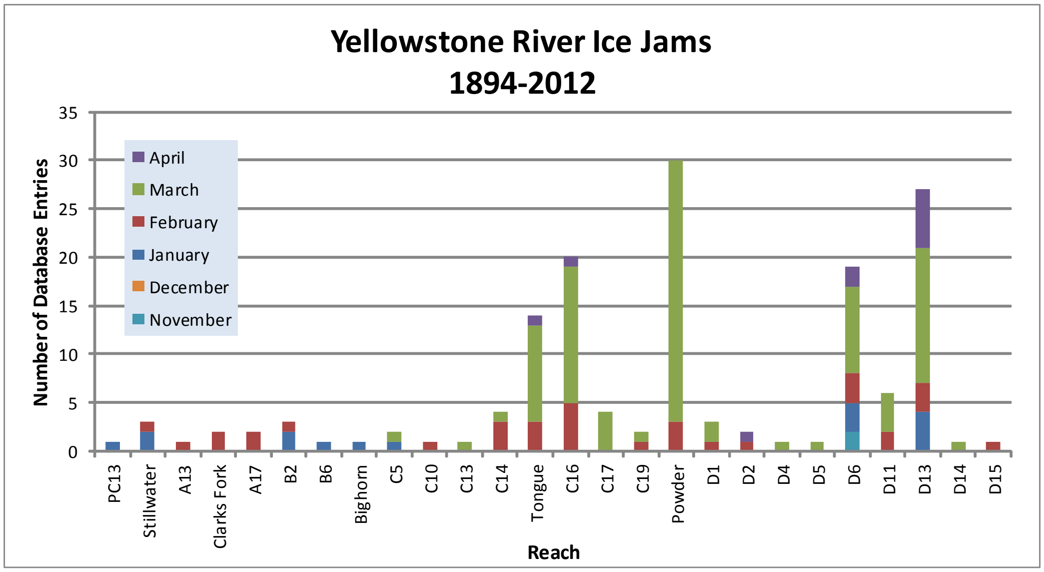
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Car Bodies	0	0	0	0	0	0	46	0
Rock RipRap	666	843	0	0	0	305	0	0
Totals	**666**	**843**	**0**	**0**	**0**	**305**	**46**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	52,003	40,222	1.77	1950 to 1976:	-5.93%
1976	52,642	35,178	1.67	1976 to 1995:	-5.98%
1995	52,942	30,099	1.57	1995 to 2001:	11.74%
2001	53,165	40,014	1.75	1950 to 2001:	-1.17%
Change 1950 - 2001	**1,162**	**-209**	**-0.02**		

Length of Side Channels Blocked

Pre-1950s (ft)	9,079
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	148	3.5%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	235	5.6%		
Abandoned Railroad	823	19.4%		
Transportation (Interstate and other roads)	32	0.7%		
Total Not Isolated (Ac)	2998		2555	
Total Floodplain Area (Ac)	4235		3894	
Total Isolated (Ac)	**1237**	**29.2%**	**1340**	**46.8%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	143	0	197	**340**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
562	1,124	3,703	184	5%	78	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	35	0.9%
	Public Road	1	0.0%
RipRap			
	Railroad	0	0.0%
	Non-Irrigated	58	1.5%
	Irrigated	41	1.1%
Dike/Levee			
	Railroad	81	2.1%
	Totals	**216**	**5.7%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
845.2	0.0	198.7	59.4	36.7

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	76	116	132	128	0.9%	1.3%	1.5%	1.5%
	Totals	**76**	**116**	**132**	**128**	**0.9%**	**1.3%**	**1.5%**	**1.5%**
Agricultural Land									
	Non-Irrigated	3,205	3,502	3,791	3,756	36.5%	39.9%	43.2%	42.8%
	Irrigated	3,834	3,488	3,306	3,296	43.7%	39.8%	37.7%	37.6%
	Totals	**7,038**	**6,991**	**7,097**	**7,052**	**80.2%**	**79.7%**	**80.9%**	**80.4%**
Channel									
	Channel	1,435	1,424	1,347	1,395	16.4%	16.2%	15.4%	15.9%
	Totals	**1,435**	**1,424**	**1,347**	**1,395**	**16.4%**	**16.2%**	**15.4%**	**15.9%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	2	2	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**2**	**2**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	68	68	68	68	0.8%	0.8%	0.8%	0.8%
	Interstate	0	20	20	20	0.0%	0.2%	0.2%	0.2%
	Railroad	95	95	49	49	1.1%	1.1%	0.6%	0.6%
	Totals	**163**	**183**	**137**	**137**	**1.9%**	**2.1%**	**1.6%**	**1.6%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	40	42	42	42	0.5%	0.5%	0.5%	0.5%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	18	13	13	13	0.2%	0.1%	0.1%	0.1%
	Urban Industrial	2	4	4	4	0.0%	0.1%	0.1%	0.1%
	Totals	**61**	**59**	**59**	**59**	**0.7%**	**0.7%**	**0.7%**	**0.7%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	429	0.0%	0.0%	0.0%	6.1%	0.0%	0.0%	6.1%	6.1%
	Flood	3,834	3,488	3,306	2,867	54.5%	49.9%	46.6%	40.6%	-4.6%	-3.3%	-5.9%	-13.8%
	Totals	**3,834**	**3,488**	**3,306**	**3,296**	**54.5%**	**49.9%**	**46.6%**	**46.7%**	**-4.6%**	**-3.3%**	**0.2%**	**-7.7%**

Non-Irrigated												
Multi-Use	2,880	3,188	3,553	3,491	40.9%	45.6%	50.1%	49.5%	4.7%	4.5%	-0.6%	8.6%
Hay/Pasture	325	314	237	265	4.6%	4.5%	3.3%	3.8%	-0.1%	-1.1%	0.4%	-0.9%
Totals	**3,205**	**3,502**	**3,791**	**3,756**	**45.5%**	**50.1%**	**53.4%**	**53.3%**	**4.6%**	**3.3%**	**-0.2%**	**7.7%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.2	0.7	0.9	0.3	2.9	2.4	2.4	1.0	0.7
Max	43.5	82.2	150.0	113.2	101.4	109.1	75.9	89.3	126.7
Average	8.5	16.7	19.7	28.5	30.8	30.9	24.2	19.9	24.7
Sum	264.3	300.0	374.8	597.9	646.9	617.8	266.7	258.1	346.0

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	147.5
Channel to Riparian (acres)	358.8
Riparian Encroachment (acres)	**211.3**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	368.8
1950s Floodplain Mapped as 2011 Channel (Ac)	90.9
Total Recruitment (1950s to 2011)(Ac)	**459.6**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	23.3	122.7	84.4	0.0	**230.4**
Acres/Valley Mile	2.9	15.3	10.6	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	205.60	2.85%	25.22	1.65	42.31	39.28

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
✓	✓	Bigmouth buffalo
✓	✓	Black bullhead
✓	✓	Black crappie
✓	✓	Blue sucker
✓	✓	Bluegill
✓	✓	Brook stickleback
✓	✓	Brown trout
✓	✓	Burbot
		Catfish species
✓	✓	Channel catfish
✓	✓	Common carp
✓	✓	Creek chub
✓	✓	Emerald shiner
✓	✓	Fathead minnow
✓	✓	Flathead chub
✓	✓	Freshwater drum
✓	✓	Goldeye
✓	✓	Green sunfish
✓	✓	Lake chub
	✓	Largemouth bass
✓	✓	Longnose dace
✓	✓	Longnose sucker
✓	✓	Minnow species
		Mottled sculpin
	✓	Mountain sucker
✓	✓	Mountain whitefish
✓	✓	Northern pike
✓	✓	Northern plains killifish
		Northern redbelly dace
		Pallid sturgeon
	✓	Pumpkinseed
		Rainbow trout
✓	✓	River carpsucker
	✓	Rock bass
✓	✓	Sand shiner
✓	✓	Sauger
✓	✓	Shorthead redhorse
		Shortnose gar
✓	✓	Shovelnose sturgeon
		Sicklefin chub
✓	✓	Smallmouth bass
✓	✓	Smallmouth buffalo
✓	✓	Stonecat
		Sturgeon chub
✓	✓	Sucker species
	✓	Sunfish species
✓	✓	Walleye
✓	✓	Western silvery minnow
		White bass
✓	✓	White crappie
✓	✓	White sucker
	✓	Yellow bullhead
		Yellow perch

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	465.9	278.0	20.6%
Rip Rap Bottom	63.8	53.5	4.0%
Rip Rap Margin	30.4	40.1	3.0%
Terrace Pool		20.8	1.5%
Secondary Channel	108.6	76.3	5.7%
Secondary Channel (Seasonal)	145.6	109.7	8.1%
Channel Crossover	231.4	190.9	14.2%
Point Bar		94.8	7.0%
Side Bar		83.0	6.2%
Mid-channel Bar		38.1	2.8%
Island	301.1	313.7	23.3%
Dry Channel		47.9	3.6%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Rosebud	**Upstream River Mile**	214.8
Classification	PCM/I: Partially confined meandering/islands	**Downstream River Mile**	208.1
General Location	Hathaway	**Length**	6.70 mi (10.78 km)
General Comments	Valley bottom crossover		

Narrative Summary

Reach C13 is 6.7 miles long and extends from RM 215 to RM 208 in Rosebud County. The reach classified as Partially Confined Meandering with Islands (PCM/I), indicating some influence of the valley wall, a main meandering channel thread, and numerous meander cutoffs that have generated large islands. Within this reach the river crosses the valley bottom from the southern bluff line in the upper portion of the reach to the northern bluff line downstream. The length of river between bluff lines is about three miles. Reach C13 locally exhibits very rapid meander migration; at RM 211 for example, the river has migrated 960 feet to the northwest over the last 50 years. At this location the river is now within 65 feet of the abandoned Milwaukee rail line which forms a defacto flood control levee on the north side of the river.

As of 2011 there were about three miles of riprap and flow deflectors protecting 26 percent of the total bankline in Reach C13, including 13,400 feet of rock riprap, 750 feet of concrete riprap, and 4,600 feet of flow deflectors. Most of the rock riprap is protecting the rail line on the south bluff line and the abandoned rail line on the north bluff line. Another 1,350 feet of bankline is protected by old car bodies at RM 201R. All of the flow deflectors, concrete riprap, and car bodies are protecting irrigated fields. Between 2001 and 2011, about 4,000 feet of flow deflectors that were mapped at RM 212.3R were evidently destroyed. It is difficult to tell from the imagery alone whether all of these flow deflectors were flanked, however at RM 212.0, flow deflectors are sitting in the river about 60 feet off of the bank.

Since 1950, a side channel that is about 4,600 feet long was blocked at RM 211.5R. This channel cuts through the core of a large meander, and appears to be naturally reactivating as the bendway translates down the river valley.

Similar to other reaches downstream of the Bighorn River confluence, the river channel has become smaller in Reach C13 since 1950. In 1950, the bankfull footprint was about 76 acres larger than it was in 2001, and riparian mapping shows about 120 acres of riparian encroachment into old channel areas. Floodplain turnover rates are also slightly lower; from 1950-1975 the average annual rate of floodplain turnover was 5.0 acres per year, and since 1975 it has been 4.1 acres per year.

Over 600 acres of the 100-year floodplain has become isolated from the river due to flow alterations, agricultural development, and the abandoned railroad grade. In total, 20 percent of the entire historic 100-year floodplain has become isolated. Isolation of the 5-year floodplain has been even more substantial; 921 acres or 45 percent of the 5-year floodplain has become isolated at that frequency event. Much of this isolated 5-year floodplain is on flood irrigated fields both north and south of the river.

One ice jam was reported in the reach as a break-up event that occurred on March 15, 2011. No damages were reported.

A total of 221 acres of land that would normally be in the river's natural Channel Migration Zone (CMZ) have become restricted by physical features, which represents about 11 percent of the total CMZ area.

Land uses in Reach C13 are predominantly agricultural, with some conversion from flood irrigation to pivot since 1950. As of 2011 there were about 330 acres under pivot irrigation in the reach. Irrigation development largely occurred prior to 1950, but additional development since then has included riparian clearing; between 1950 and 2011 about 133 acres of riparian area was cleared for irrigation, which is 11 percent of the total 1950s riparian area.

There are 216 acres of mapped Russian olive in the reach, which is notably concentrated in abandoned side channels. Reach C13 also has fairly extensive mapped wetlands; there are over 32 mapped wetland acres per valley mile in the reach, most of which is emergent marsh and wet meadows in floodplain swales.

Reach C13 was sampled as part of the fisheries study. A total of 27 species were sampled in the reach, including Sauger and Blue Sucker, both of which have been identified as Species of Concern by the Montana Natural Heritage Program.

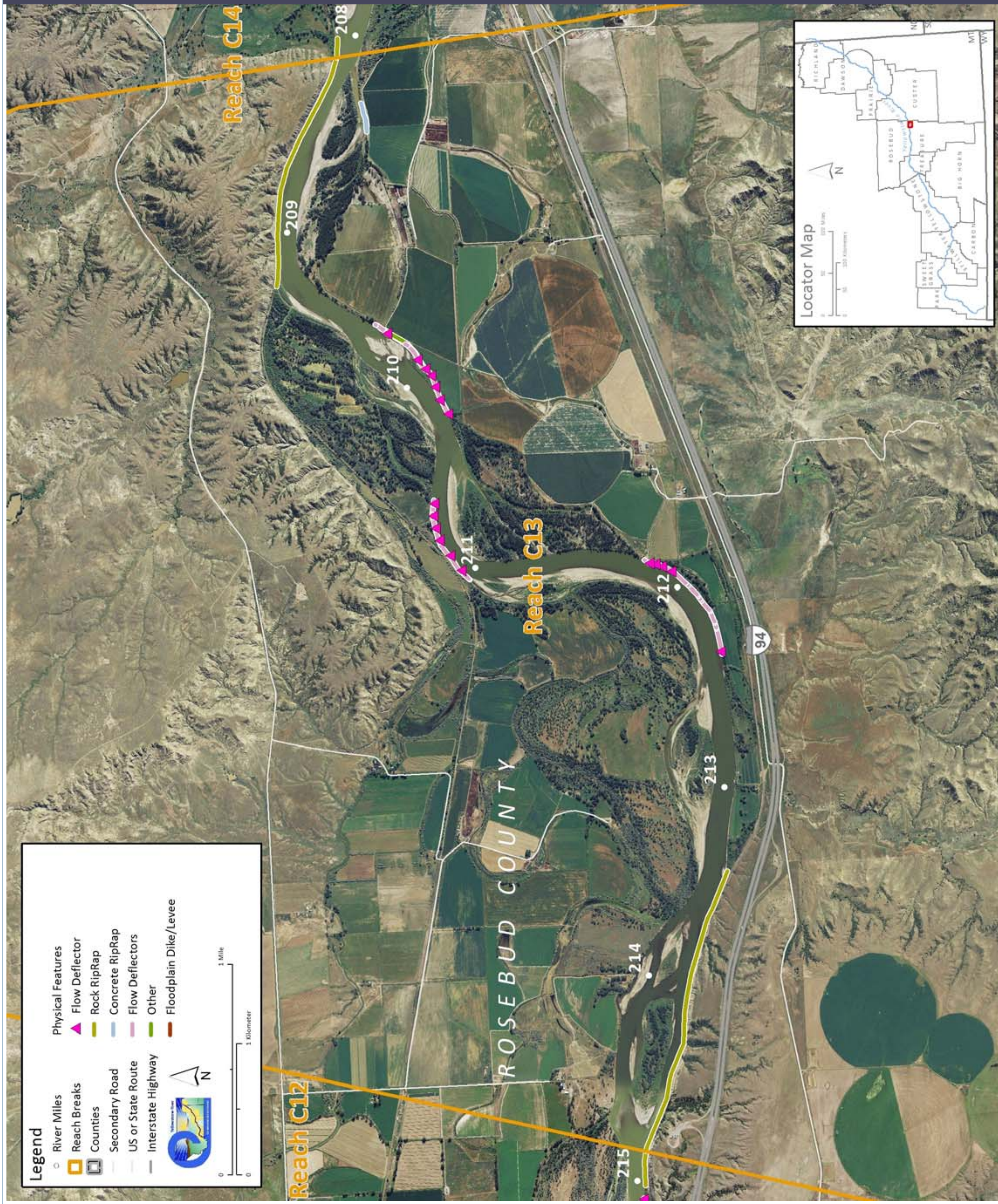
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped by 18 percent and the 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,840 cfs to 3,070 cfs with human development, a reduction of 37 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,320 cfs under unregulated conditions to 3,380 cfs under regulated conditions, a reduction of 47 percent.

Fall and winter base flows have increased in Reach C13 by about 60 percent.

CEA-Related observations in Reach C13 include:
•Floodplain isolation by the abandoned Milwaukee rail line on the north bank.
•Blocking of side channels
•Post-1950s riparian clearing for irrigation development

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C13 include:
•Removal of flanked barb at RM 212.
•Side channel reactivation at RM 211.6 R.
•CMZ Management due to extent of CMZ restriction (11 percent)

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	24.1	149.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		61,900	77,800	88,100	110,000	120,000	142,000	4,840	6,320
Regulated		47,300	61,700	70,900	90,600	98,800	118,000	3,070	3,380
% Change		-23.59%	-20.69%	-19.52%	-17.64%	-17.67%	-16.90%	-36.57%	-46.52%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	60,600	22,700	6,070
	Regulated	46,900	13,700	4,420
	% Change	**-23%**	**-40%**	**-27%**
Summer	Unregulated	42,700	13,400	6,320
	Regulated	32,500	8,320	3,380
	% Change	**-24%**	**-38%**	**-47%**
Fall	Unregulated	9,130	5,540	2,300
	Regulated	10,500	6,890	3,640
	% Change	**15%**	**24%**	**58%**
Winter	Unregulated	11,700	4,940	2,020
	Regulated	12,300	6,030	3,260
	% Change	**5%**	**22%**	**61%**
Annual	Unregulated	45,400	7,920	2,790
	Regulated	34,100	7,380	3,630
	% Change	**-25%**	**-7%**	**30%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	8/7/96 - 7/12/96	B/W		6295000	27600
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/08/2005	color	1-meter pixels	6309000	18800
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2009	NAIP	7/15/2009	Color	1-meter pixels	6309000	26400
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/15/2011	Color	1-meter pixels	6309000	58000
2013	NAIP	07/20/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	13,404	18.8%	13,404	18.8%	0
	Flow Deflectors	1,753	2.5%	1,327	1.9%	-426
	Concrete RipRap	744	1.0%	744	1.0%	0
	Car Bodies	1,354	1.9%	1,354	1.9%	0
	Between Flow Deflectors	6,783	9.5%	3,240	4.6%	-3,543
	Feature Type Totals	**24,038**	**33.8%**	**20,069**	**28.2%**	**-3,969**
	Reach Totals	**24,038**	**33.8%**	**20,069**	**28.2%**	**-3,969**

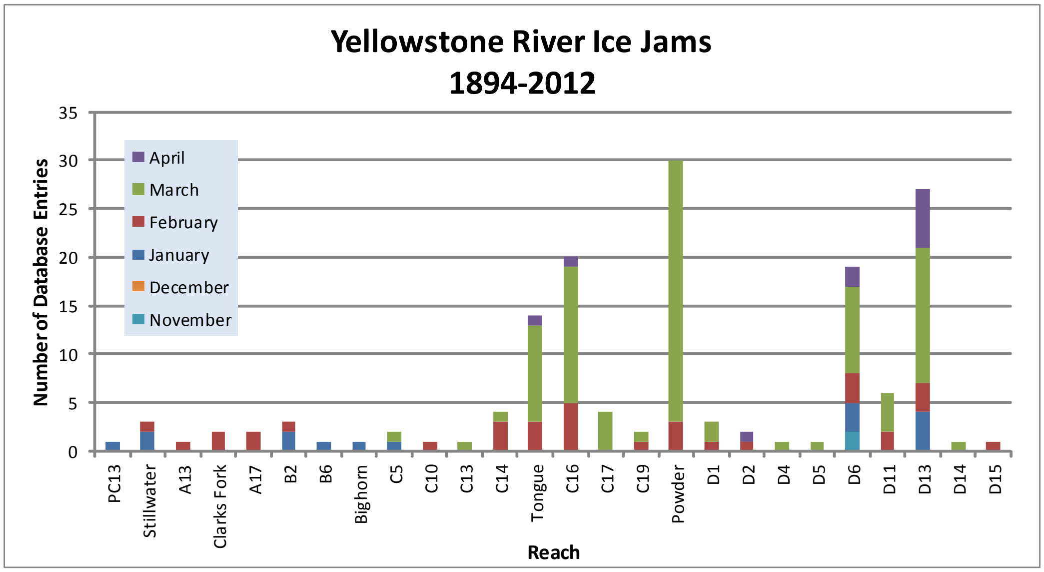
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Car Bodies	1,355	0	0	0	0	0	0	0
Concrete RipRap	745	0	0	0	0	0	0	0
Flow Deflectors/Between FDs	7,111	0	0	0	0	1,312	0	0
Rock RipRap	0	0	0	0	0	8,226	0	0
Totals	**9,210**	**0**	**0**	**0**	**0**	**9,538**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
3/15/2011	Break-up		

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	35,504	14,748	1.42
1976	35,672	24,681	1.69
1995	35,586	25,047	1.70
2001	35,591	22,387	1.63
Change 1950 - 2001	**88**	**7,639**	**0.21**

	% Change in Braiding
1950 to 1976:	19.54%
1976 to 1995:	0.71%
1995 to 2001:	-4.39%
1950 to 2001:	15.09%

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	4,575

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	142	4.5%		
Agriculture (generally relates to field boundaries)	378	11.9%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	120	3.8%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	2550		1821	
Total Floodplain Area (Ac)	3191		2742	
Total Isolated (Ac)	**641**	**20.1%**	**921**	**45.3%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	185	0	0	**185**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
396	793	1,941	222	11%	115	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Irrigated	67	3.2%
RipRap			
	Non-Irrigated	0	0.0%
	Irrigated	20	1.0%
Flow Deflectors			
	Railroad	59	2.9%
	Irrigated	76	3.7%
	Totals	**222**	**10.8%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
378.1	0.0	0.0	0.0	7.9

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	60	141	144	133	0.8%	1.8%	1.8%	1.7%
	Totals	**60**	**141**	**144**	**133**	**0.8%**	**1.8%**	**1.8%**	**1.7%**
Agricultural Land									
	Non-Irrigated	3,328	3,486	3,865	3,881	42.0%	43.9%	48.7%	48.9%
	Irrigated	3,571	3,114	2,750	2,739	45.0%	39.3%	34.7%	34.5%
	Totals	**6,900**	**6,600**	**6,615**	**6,620**	**87.0%**	**83.2%**	**83.4%**	**83.5%**
Channel									
	Channel	868	892	907	913	10.9%	11.2%	11.4%	11.5%
	Totals	**868**	**892**	**907**	**913**	**10.9%**	**11.2%**	**11.4%**	**11.5%**
ExUrban									
	ExUrban Other	0	24	24	24	0.0%	0.3%	0.3%	0.3%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**24**	**24**	**24**	**0.0%**	**0.3%**	**0.3%**	**0.3%**
Transportation									
	Public Road	39	48	48	48	0.5%	0.6%	0.6%	0.6%
	Interstate	0	160	160	160	0.0%	2.0%	2.0%	2.0%
	Railroad	65	67	34	34	0.8%	0.8%	0.4%	0.4%
	Totals	**105**	**275**	**242**	**242**	**1.3%**	**3.5%**	**3.1%**	**3.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	328	328	0.0%	0.0%	5.0%	4.9%	0.0%	5.0%	0.0%	4.9%
	Flood	3,571	3,114	2,423	2,412	51.8%	47.2%	36.6%	36.4%	-4.6%	-10.6%	-0.2%	-15.3%
	Totals	**3,571**	**3,114**	**2,750**	**2,739**	**51.8%**	**47.2%**	**41.6%**	**41.4%**	**-4.6%**	**-5.6%**	**-0.2%**	**-10.4%**

Non-Irrigated

Multi-Use	3,183	3,413	3,319	3,700	46.1%	51.7%	50.2%	55.9%	5.6%	-1.5%	5.7%	9.7%
Hay/Pasture	145	73	546	181	2.1%	1.1%	8.3%	2.7%	-1.0%	7.2%	-5.5%	0.6%
Totals	**3,328**	**3,486**	**3,865**	**3,881**	**48.2%**	**52.8%**	**58.4%**	**58.6%**	**4.6%**	**5.6%**	**0.2%**	**10.4%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.2	0.7	1.3	0.3	1.0	1.0	6.1	0.1	3.0
Max	87.6	77.2	32.2	376.6	197.6	155.3	90.7	74.5	98.6
Average	12.8	13.6	10.3	60.4	34.6	34.0	30.9	19.1	27.8
Sum	295.3	326.1	153.8	844.9	760.8	781.6	154.7	152.5	194.5

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	121.3
Channel to Riparian (acres)	238.3
Riparian Encroachment (acres)	**117.1**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	243.1
1950s Floodplain Mapped as 2011 Channel (Ac)	77.9
Total Recruitment (1950s to 2011)(Ac)	**321.0**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	21.1	134.3	54.1	0.0	**209.6**
Acres/Valley Mile	3.5	22.5	9.1	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	215.78	3.79%	10.28	9.98	29.74	7.23

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
	✓	Bigmouth buffalo
	✓	Black bullhead
✓	✓	Black crappie
✓	✓	Blue sucker
	✓	Bluegill
✓	✓	Brook stickleback
	✓	Brown trout
✓	✓	Burbot
		Catfish species
✓	✓	Channel catfish
✓	✓	Common carp
	✓	Creek chub
✓	✓	Emerald shiner
✓	✓	Fathead minnow
✓	✓	Flathead chub
✓	✓	Freshwater drum
✓	✓	Goldeye
✓	✓	Green sunfish
	✓	Lake chub
	✓	Largemouth bass
✓	✓	Longnose dace
✓	✓	Longnose sucker
✓	✓	Minnow species
		Mottled sculpin
✓	✓	Mountain sucker
	✓	Mountain whitefish
	✓	Northern pike
✓	✓	Northern plains killifish
		Northern redbelly dace
		Pallid sturgeon
	✓	Pumpkinseed
		Rainbow trout
✓	✓	River carpsucker
	✓	Rock bass
✓	✓	Sand shiner
✓	✓	Sauger
✓	✓	Shorthead redhorse
		Shortnose gar
	✓	Shovelnose sturgeon
		Sicklefin chub
✓	✓	Smallmouth bass
✓	✓	Smallmouth buffalo
✓	✓	Stonecat
		Sturgeon chub
✓	✓	Sucker species
	✓	Sunfish species
	✓	Walleye
✓	✓	Western silvery minnow
		White bass
	✓	White crappie
✓	✓	White sucker
	✓	Yellow bullhead
		Yellow perch

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	88.5	66.4	7.3%
Rip Rap Bottom	200.9	152.6	16.8%
Rip Rap Margin	124.6	93.0	10.2%
Secondary Channel		8.8	1.0%
Secondary Channel (Seasonal)	143.5	115.7	12.8%
Channel Crossover	149.9	91.9	10.1%
Point Bar		41.8	4.6%
Side Bar		33.6	3.7%
Mid-channel Bar		16.0	1.8%
Island	199.8	199.8	22.0%
Dry Channel		87.5	9.6%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Rosebud	**Upstream River Mile**	208.1
Classification	PCM/I: Partially confined meandering/islands	**Downstream River Mile**	195.9
General Location	Sheffield	**Length**	12.20 mi (19.63 km)
General Comments	Series of meander bends		

Narrative Summary

Reach C14 is 12.2 miles long and is located near Sheffield, which is about 15 miles upstream of Miles City. The reach straddles the Rosebud/Custer County Line. The reach is characterized by a dominant main thread that shows a distinct meandering pattern, with several islands persisting where meander bends have historically cut off. The river intermittently flows along the south valley wall. As a result it is classified as Partially Confined Meandering with Islands (PCM/I). In this section of river the valley bottom is consistently about 1.8 miles wide, and bound by Tertiary-age Fort Union Formation. The active meanderbelt of the Yellowstone River is about 3,000 feet wide.

The large meander features in Reach C14 have experienced significant migration since 1950 and also in recent years; one site at RM 204.5 migrated 977 feet southward between 1950 and 2001, and then over the next ten years continued to migrate another 400 feet so that it is now at the toe of the active rail line. At RM 200.5, the river has migrated 700 feet northward since 2001; eroding out irrigated lands and threatening structures.

As of 2011 there were about four miles of armor protecting 17 percent of the total bankline in Reach C14, including 15,087 feet of rock riprap and 6,300 feet of flow deflectors. Most of the rock riprap is protecting the rail line as it flows along the south bluff of Fort Union Formation, whereas flow deflectors are more commonly used to protect agricultural land. Between 2001 and 2011, about 3,000 feet of flow deflectors were evidently destroyed. Barbs can be seen in the river at RM 205.3R; the bank behind has since been partially armored with rock riprap. Another barb was flanked at RM 204.7L, and the river has migrated over 200 feet behind that structure towards the rail line. Another series of barbs were flanked at RM 203.6L and have since been replaced by rock riprap. Those flanked rock structures are visible on the 2011 air photos almost 200 feet out into the channel. At RM 200.8L, new riprap was built after older armor scoured out in 2011, which was followed by hundreds of feet of northward bank migration during the 2011 flood. Some of the new riprap appears to be trenched behind the bank. About 1,300 feet of rock riprap mapped in 2001 on the left bank at RM 196.9 has been flanked, and is now up to 70 feet out in the river.

Prior to 1950, about 3 miles of side channels were blocked in Reach C14. Chute channels formed through meander tabs have been blocked by small dikes such as at RM 198. Several historic anabranching channels appear to have been blocked prior to 1950 such as at RM 207.8. These areas provide excellent restoration/mitigation opportunities for side channel re-activation.

Similar to other reaches downstream of the Bighorn River confluence, the river channel has become smaller in Reach C14 since 1950. In 1950, the bankfull footprint was about 38 acres larger than it was in 2001, and riparian mapping shows about 208 acres of riparian encroachment into old channel areas. Floodplain turnover rates are also slightly lower; from 1950-1975 the average annual rate of floodplain turnover was 15.6 acres per year, and since 1975 it has been 12.5 acres per year.

Over two thousand acres of the 100-year floodplain has become isolated from the river due to flow alterations, agricultural development, and the abandoned railroad grade. In total, 40 percent of the entire historic 100-year floodplain has become isolated. Most of the isolation is associated with agricultural land development (29 percent of the historic floodplain), with another 10 percent of the isolation due to the abandoned rail grade. Isolation of the 5-year floodplain has been even more substantial; 2,321 acres or 59 percent of the 5-year floodplain has become isolated at that frequency event. Much of this isolated 5-year floodplain is on flood irrigated fields north of the river.

Bank armor on the north side of the river commonly narrows the natural meanderbelt of the river, which has resulted in large extents of the CMZ being restricted to migration. About 740 acres which represents 16 percent of the total CMZ has become restricted by physical features.

Four ice jams have been reported in the reach, including February of 1996, 1997, and 1998, and March of 2003. All of the ice jams in the 1990s were associated with lowland flooding.

One dump site was mapped on the left bank at RM 196.3.

Reach C14 has seen extensive riparian clearing since 1950s. Typically, riparian clearing for agriculture occurred prior to 1950 along the Yellowstone River. In this reach, however, 760 acres of riparian area were cleared since 1950, which represents 30 percent of the total 1950s riparian corridor. In several cases, this includes riparian clearing on large meander tabs. With this clearing, the reach has seen a substantial loss of forest area considered at low risk of cowbird parasitism. In 1950, the reach had 91.8 acres of such forest per valley mile and by 2001 that forest extent had dropped to 51.4 acres per valley mile.

Reach C14 has fairly extensive mapped wetland area; there are over 45 acres of mapped wetlands per valley mile, most of which is emergent marsh and wet meadow. A total of 22 acres of Russian olive were mapped in the reach, which reflects an abrupt reduction in Russian olive extent relative to upstream, where Reaches C10 through C13 have on the order of 200 acres of RO over similar valley distances.

Reach C14 was sampled as part of the fisheries study. A total of 36 species were sampled in the reach, including Sauger which has been identified as Species of Concern by the Montana Natural Heritage Program.

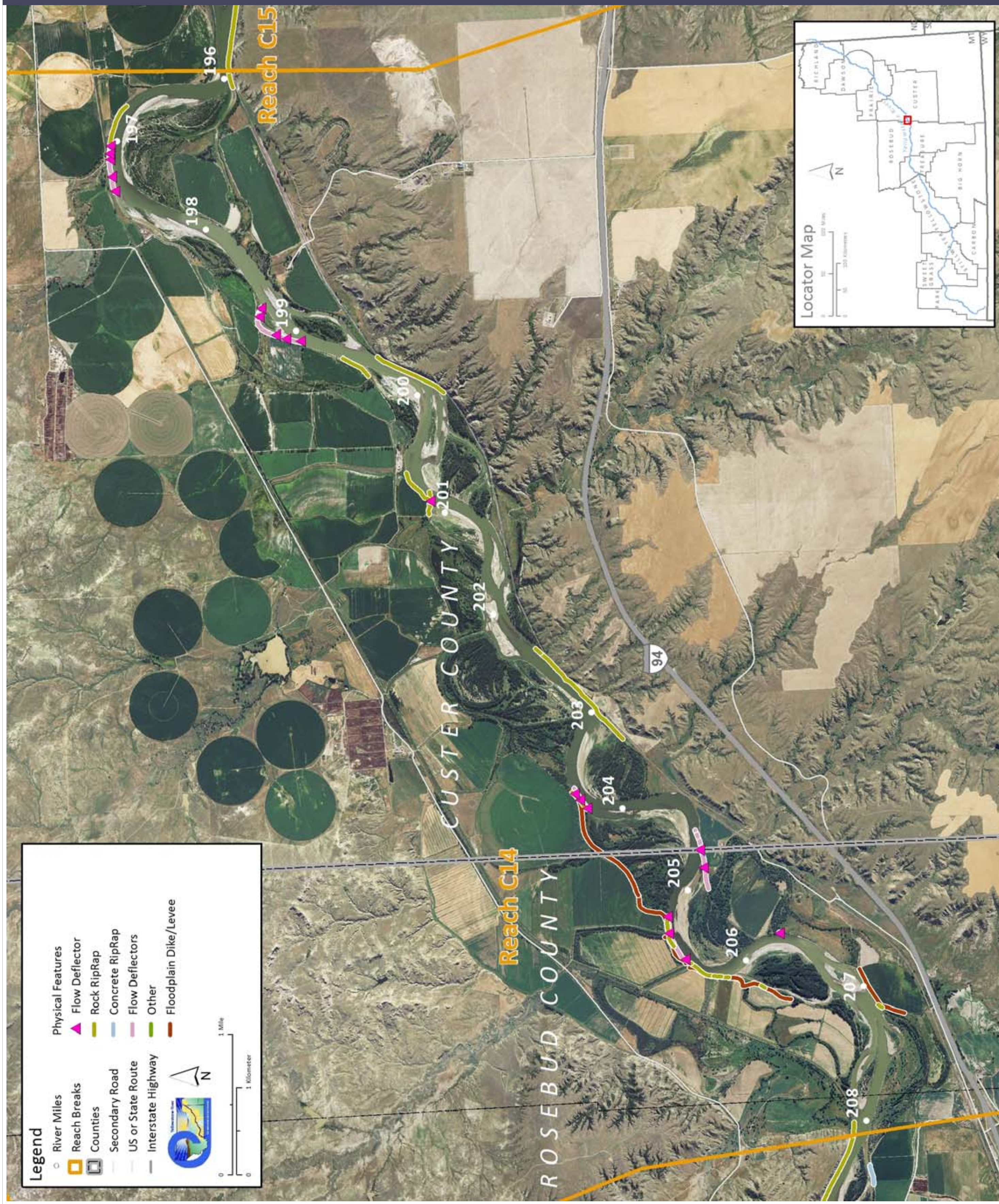
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped by 18 percent and the 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,850 cfs to 3,070 cfs with human development, a reduction of 37 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,330 cfs under unregulated conditions to 3,390 cfs under regulated conditions, a reduction of 47 percent.

Fall and winter base flows have increased in Reach C14 by about 60 percent.

CEA-Related observations in Reach C14 include:
•Passive side channel abandonment due to flow alterations
•Flanking of barb structures on migrating meander bends
•Extensive floodplain isolation by agricultural dikes and abandoned railroad grade
•Pre-1950s blocking of side channels by agricultural dikes
•Armoring of bluff pool habitat against active railroad
•Floodplain isolation by the abandoned Milwaukee rail line on the north bank
•Post-1950s riparian clearing for irrigation development

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C14 include:
•Removal of flanked barb at RM 205.3
•Side channel reactivation at RM 208L
•CMZ Management due to extent of CMZ restriction (11 percent)
•Dump removal on left bank at RM 196.3L
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	11.9	156.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		61,900	77,800	88,100	110,000	120,000	142,000	4,850	6,330
Regulated		47,300	61,700	70,900	90,500	98,600	118,000	3,070	3,390
% Change		-23.59%	-20.69%	-19.52%	-17.73%	-17.83%	-16.90%	-36.70%	-46.45%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	60,600	22,700	6,090
	Regulated	46,900	13,700	4,430
	% Change	**-23%**	**-40%**	**-27%**
Summer	Unregulated	42,800	13,500	6,330
	Regulated	32,500	8,330	3,390
	% Change	**-24%**	**-38%**	**-46%**
Fall	Unregulated	9,140	5,550	2,300
	Regulated	10,500	6,890	3,640
	% Change	**15%**	**24%**	**58%**
Winter	Unregulated	11,700	4,950	2,020
	Regulated	12,300	6,030	3,260
	% Change	**5%**	**22%**	**61%**
Annual	Unregulated	45,500	7,940	2,790
	Regulated	34,100	7,390	3,630
	% Change	**-25%**	**-7%**	**30%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	7/7/96 - 8/7/96	B/W		6295000	39800
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/08/2005	color	1-meter pixels	6309000	18800
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2009	NAIP	7/15/2009	Color	1-meter pixels	6309000	26400
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2011	NAIP	7/15/2011	Color	1-meter pixels	6309000	58000
2013	NAIP	07/21/2013	color	1-meter pixels	6309000	
2013	NAIP	07/20/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	13,314	10.4%	15,087	11.7%	1,773
	Flow Deflectors	1,821	1.4%	1,638	1.3%	-184
	Between Flow Deflectors	7,431	5.8%	4,657	3.6%	-2,774
	Feature Type Totals	**22,567**	**17.6%**	**21,382**	**16.6%**	**-1,185**
Floodplain Control						
	Transportation Encroachment	4,433	3.5%	4,433	3.5%	0
	Floodplain Dike/Levee	14,808	11.5%	14,882	11.6%	73
	Feature Type Totals	**19,241**	**15.0%**	**19,315**	**15.0%**	**73**
	Reach Totals	**41,808**	**32.5%**	**40,697**	**31.7%**	**-1,111**

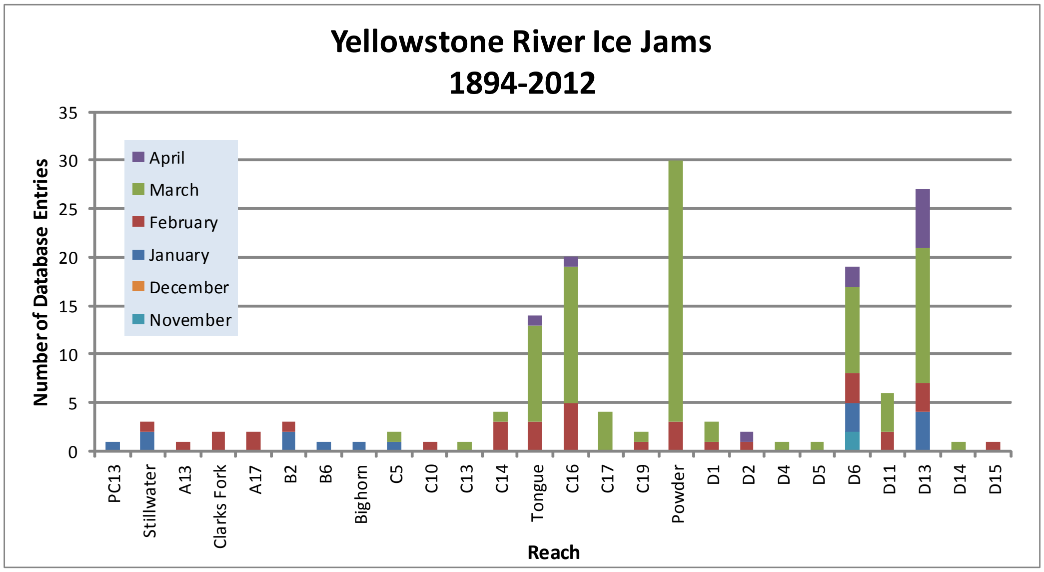
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	4,257	2,286	0	0	0	1,761	0	0
Rock RipRap	4,562	0	0	0	0	11,110	0	0
Totals	**8,820**	**2,286**	**0**	**0**	**0**	**12,871**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
2/7/1996	Break-up	208	Flooding
2/20/1997	Freeze-up	208	Lowland flooding
2/3/1998	Break-up	208	Lowland flooding
3/15/2003	Break-up		?

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	66,789	44,239	1.66	**1950 to 1976:**	16.56%
1976	61,868	58,008	1.94	**1976 to 1995:**	-7.30%
1995	64,341	51,220	1.80	**1995 to 2001:**	-22.77%
2001	64,232	24,859	1.39	**1950 to 2001:**	-16.56%
Change 1950 - 2001	**-2,557**	**-19,380**	**-0.28**		

Length of Side Channels Blocked

Pre-1950s (ft)	14,986
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	27	0.5%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	1474	29.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	52	1.0%		
Abandoned Railroad	495	9.7%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	3039		2922	
Total Floodplain Area (Ac)	5088		5243	
Total Isolated (Ac)	**2049**	**40.3%**	**2321**	**59.1%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	269	0	0	**269**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
575	1,150	4,432	737	17%	306	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	63	1.3%
RipRap/Flow Deflectors			
	Irrigated	250	5.3%
RipRap			
	Railroad	41	0.9%
	Non-Irrigated	45	1.0%
Flow Deflectors			
	Other Infrastructure	17	0.4%
	Non-Irrigated	77	1.6%
Dike/Levee			
	Irrigated	247	5.2%
	Totals	**739**	**15.6%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
1015.0	0.0	112.6	3.9	23.9

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	77	141	109	106	0.7%	1.3%	1.0%	0.9%
	Totals	**77**	**141**	**109**	**106**	**0.7%**	**1.3%**	**1.0%**	**0.9%**
Agricultural Land									
	Non-Irrigated	6,908	5,532	5,146	4,958	61.7%	49.4%	45.9%	44.3%
	Irrigated	2,517	3,507	3,982	4,058	22.5%	31.3%	35.5%	36.2%
	Totals	**9,425**	**9,040**	**9,128**	**9,017**	**84.1%**	**80.7%**	**81.5%**	**80.5%**
Channel									
	Channel	1,569	1,806	1,786	1,901	14.0%	16.1%	15.9%	17.0%
	Totals	**1,569**	**1,806**	**1,786**	**1,901**	**14.0%**	**16.1%**	**15.9%**	**17.0%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	6	6	0.0%	0.0%	0.1%	0.1%
	Totals	**0**	**0**	**6**	**6**	**0.0%**	**0.0%**	**0.1%**	**0.1%**
Transportation									
	Public Road	35	47	47	47	0.3%	0.4%	0.4%	0.4%
	Interstate	0	66	66	66	0.0%	0.6%	0.6%	0.6%
	Railroad	95	101	58	58	0.9%	0.9%	0.5%	0.5%
	Totals	**131**	**214**	**171**	**171**	**1.2%**	**1.9%**	**1.5%**	**1.5%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	154	345	660	0.0%	1.7%	3.8%	7.3%	1.7%	2.1%	3.5%	7.3%
	Flood	2,517	3,353	3,637	3,398	26.7%	37.1%	39.8%	37.7%	10.4%	2.7%	-2.2%	11.0%
	Totals	**2,517**	**3,507**	**3,982**	**4,058**	**26.7%**	**38.8%**	**43.6%**	**45.0%**	**12.1%**	**4.8%**	**1.4%**	**18.3%**

Non-Irrigated													
	Multi-Use	6,439	5,123	4,666	4,531	68.3%	56.7%	51.1%	50.2%	-11.7%	-5.6%	-0.9%	-18.1%
	Hay/Pasture	469	410	481	428	5.0%	4.5%	5.3%	4.7%	-0.4%	0.7%	-0.5%	-0.2%
	Totals	**6,908**	**5,532**	**5,146**	**4,958**	**73.3%**	**61.2%**	**56.4%**	**55.0%**	**-12.1%**	**-4.8%**	**-1.4%**	**-18.3%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.5	0.5	1.6	0.3	1.1	1.9	2.5	2.8	5.3
Max	87.1	38.7	28.2	471.6	149.2	189.5	82.1	98.0	63.9
Average	17.9	7.4	9.5	58.3	34.3	37.1	29.0	24.0	22.7
Sum	554.6	376.6	218.7	1,632.8	1,133.0	1,112.4	464.0	359.6	317.1

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	412.8
Channel to Riparian (acres)	620.5
Riparian Encroachment (acres)	**207.7**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	642.4
1950s Floodplain Mapped as 2011 Channel (Ac)	130.2
Total Recruitment (1950s to 2011)(Ac)	**772.5**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	48.6	292.7	121.6	0.0	**462.9**
Acres/Valley Mile	5.0	30.0	12.5	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	21.65	0.24%	0.57	0.94	3.05	0.36

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
✓	✓	Bigmouth buffalo
✓	✓	Black bullhead
✓	✓	Black crappie
	✓	Blue sucker
✓	✓	Bluegill
✓	✓	Brook stickleback
	✓	Brown trout
✓	✓	Burbot
		Catfish species
✓	✓	Channel catfish
✓	✓	Common carp
✓	✓	Creek chub
✓	✓	Emerald shiner
✓	✓	Fathead minnow
✓	✓	Flathead chub
✓	✓	Freshwater drum
✓	✓	Goldeye
✓	✓	Green sunfish
✓	✓	Lake chub
	✓	Largemouth bass
✓	✓	Longnose dace
✓	✓	Longnose sucker
✓	✓	Minnow species
		Mottled sculpin
✓	✓	Mountain sucker
	✓	Mountain whitefish
✓	✓	Northern pike
✓	✓	Northern plains killifish
		Northern redbelly dace
		Pallid sturgeon
	✓	Pumpkinseed
		Rainbow trout
✓	✓	River carpsucker
✓	✓	Rock bass
✓	✓	Sand shiner
✓	✓	Sauger
✓	✓	Shorthead redhorse
		Shortnose gar
✓	✓	Shovelnose sturgeon
		Sicklefin chub
✓	✓	Smallmouth bass
✓	✓	Smallmouth buffalo
✓	✓	Stonecat
		Sturgeon chub
✓	✓	Sucker species
✓	✓	Sunfish species
	✓	Walleye
✓	✓	Western silvery minnow
		White bass
✓	✓	White crappie
✓	✓	White sucker
	✓	Yellow bullhead
		Yellow perch

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	281.9	215.6	12.1%
Rip Rap Bottom	278.9	168.1	9.4%
Rip Rap Margin	83.7	60.1	3.4%
Secondary Channel	67.4	95.2	5.3%
Secondary Channel (Seasonal)	182.6	143.0	8.0%
Channel Crossover	384.3	216.9	12.1%
Point Bar		146.2	8.2%
Side Bar		68.1	3.8%
Mid-channel Bar		75.6	4.2%
Island	507.2	507.2	28.4%
Dry Channel		90.0	5.0%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Custer	**Upstream River Mile**	195.9
Classification	PCS: Partially confined straight	**Downstream River Mile**	192.3
General Location	Horton Siding	**Length**	3.60 mi (5.79 km)
General Comments	Very low riparian vegetation		

Narrative Summary

Reach C15 is located in Custer County at Horton Siding, about seven miles upstream of Miles City. It is 3.6 miles long and classified as a Partially Confined Straight (PCS) reach type, as the river has low sinuosity and flows along the south valley wall.

As of 2011 there were about 7,600 feet of armor protecting 19 percent of the total bankline in Reach C15, the vast majority of which is rock riprap protecting the rail line as it flows along the south bluff of Fort Union Formation. There are also minor amounts of flow deflectors (80 feet) and car bodies (150 feet) in the reach.

About 17 percent of the historic 100-year floodplain has become isolated. Isolation of the 5-year floodplain has been even more substantial; 298 acres or 61 percent of the 5-year floodplain has become isolated at that frequency event. Floodplain isolation appears to be mostly due to flow alterations, although there are 35 acres if isolated 100-year floodplain behind the abandoned Milwaukee rail line embankment.

Reach C15 has lost approximately 3,000 feet of side channel length since 1950; although there is no indication that side channels were intentionally blocked.

There has been about 1,200 acres of pivot irrigation development in Reach C15 since 1950, and most of that expansion has occurred since 2001. Pivot irrigation is more extensive than flood irrigation in this area, which is somewhat unusual in the Yellowstone River valley. About 10 percent (115 acres) of the land under pivot irrigation is within the Channel Migration Zone (CMZ) of the river, making it especially prone to threats of river erosion.

Reach C15 has seen relatively extensive riparian clearing since 1950s. Typically, riparian clearing for agriculture occurred prior to 1950 along the Yellowstone River. In this reach, however, 48 acres of riparian area were cleared since 1950, which represents 20 percent of the total 1950s riparian corridor. With this clearing, the reach has seen a substantial loss of forest area considered at low risk of cowbird parasitism. In 1950, the reach had 51.3 acres of such forest per valley mile and by 2001 that forest extent had dropped to 37.2 acres per valley mile.

A total of 8 acres of Russian olive have been mapped in Reach C15.

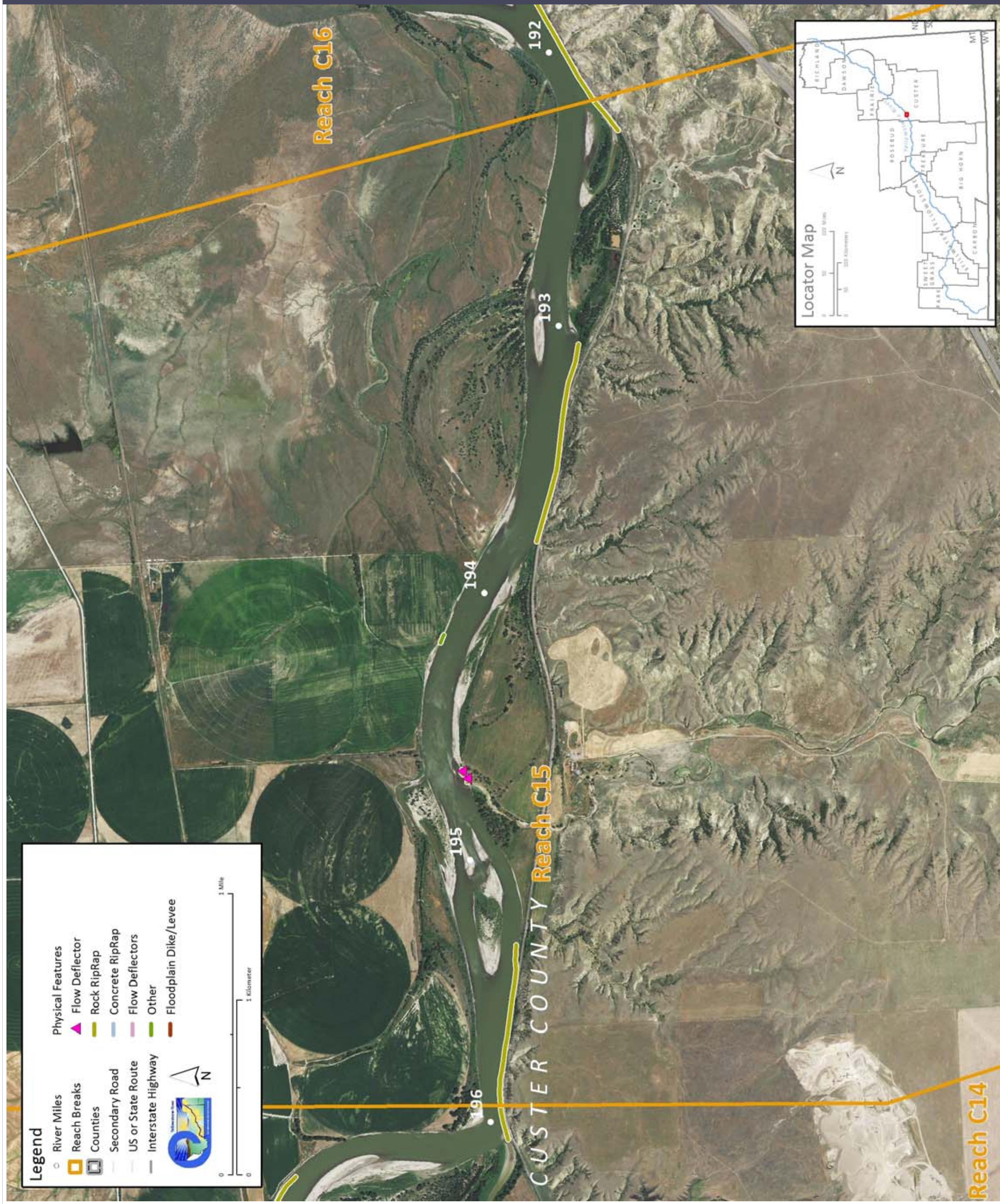
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped by 18 percent and the 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,850 cfs to 3,070 cfs with human development, a reduction of 37 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,340 cfs under unregulated conditions to 3,390 cfs under regulated conditions, a reduction of 47 percent.

Fall and winter base flows have increased in Reach C15 by over 60 percent.

CEA-Related observations in Reach C15 include:
•Passive side channel abandonment due to flow alterations
•Extensive pivot irrigation development since 2001

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C15 include:
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	8.3	168.5

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		62,000	77,800	88,100	110,000	120,000	142,000	4,850	6,340
Regulated		47,300	61,700	70,900	90,400	98,600	117,000	3,070	3,390
% Change		-23.71%	-20.69%	-19.52%	-17.82%	-17.83%	-17.61%	-36.70%	-46.53%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Season		5%	50%	95%
Spring	Unregulated	60,700	22,700	6,090
	Regulated	46,900	13,700	4,430
	% Change	**-23%**	**-40%**	**-27%**
Summer	Unregulated	42,800	13,500	6,340
	Regulated	32,600	8,330	3,390
	% Change	**-24%**	**-38%**	**-47%**
Fall	Unregulated	9,150	5,550	2,300
	Regulated	10,500	6,900	3,640
	% Change	**15%**	**24%**	**58%**
Winter	Unregulated	11,700	4,950	2,020
	Regulated	12,400	6,040	3,260
	% Change	**6%**	**22%**	**61%**
Annual	Unregulated	45,500	7,940	2,800
	Regulated	34,200	7,400	3,630
	% Change	**-25%**	**-7%**	**30%**

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	7-Jul-96	B/W		6295000	39800
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/08/2005	color	1-meter pixels	6309000	18800
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	7,814	19.8%	7,578	19.2%	-235
	Flow Deflectors	0	0.0%	80	0.2%	80
	Car Bodies	152	0.4%	152	0.4%	0
	Feature Type Totals	**7,965**	**20.2%**	**7,810**	**19.8%**	**-155**
	Reach Totals	**7,965**	**20.2%**	**7,810**	**19.8%**	**-155**

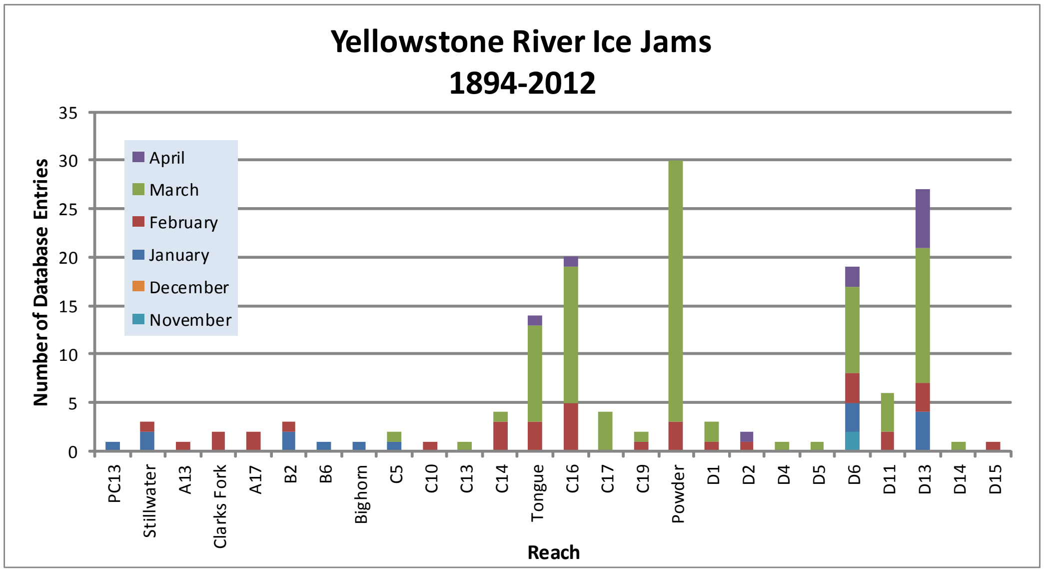
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Car Bodies	141	0	0	0	0	0	0	0
Rock RipRap	236	0	0	0	0	7,488	0	0
Totals	**377**	**0**	**0**	**0**	**0**	**7,488**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	19,497	5,895	1.30	1950 to 1976:	-12.15%
1976	19,522	2,815	1.14	1976 to 1995:	0.93%
1995	19,711	3,051	1.15	1995 to 2001:	-0.57%
2001	19,711	2,920	1.15	1950 to 2001:	-11.84%
Change 1950 - 2001	**214**	**-2,975**	**-0.15**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	122	12.5%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	12	1.2%		
Abandoned Railroad	35	3.6%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	805		560	
Total Floodplain Area (Ac)	973		859	
Total Isolated (Ac)	**168**	**17.3%**	**298**	**60.5%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	4	0	0	**4**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
180	360	720	14	2%	248	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Railroad	16	1.6%
	Totals	**16**	**1.6%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
14.0	0.0	114.9	0.0	4.5

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	6	23	42	54	0.2%	0.5%	1.0%	1.3%
	Totals	**6**	**23**	**42**	**54**	**0.2%**	**0.5%**	**1.0%**	**1.3%**
Agricultural Land									
	Non-Irrigated	3,447	2,292	1,746	1,789	81.9%	54.5%	41.5%	42.5%
	Irrigated	324	1,471	2,002	1,941	7.7%	35.0%	47.6%	46.1%
	Totals	**3,771**	**3,763**	**3,748**	**3,729**	**89.6%**	**89.4%**	**89.1%**	**88.6%**
Channel									
	Channel	391	382	390	396	9.3%	9.1%	9.3%	9.4%
	Totals	**391**	**382**	**390**	**396**	**9.3%**	**9.1%**	**9.3%**	**9.4%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	7	7	7	7	0.2%	0.2%	0.2%	0.2%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	33	34	22	22	0.8%	0.8%	0.5%	0.5%
	Totals	**40**	**41**	**29**	**29**	**1.0%**	**1.0%**	**0.7%**	**0.7%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	267	1,244	0.0%	0.0%	7.1%	33.4%	0.0%	7.1%	26.2%	33.4%
	Flood	324	1,471	1,735	696	8.6%	39.1%	46.3%	18.7%	30.5%	7.2%	-27.6%	10.1%
	Totals	**324**	**1,471**	**2,002**	**1,941**	**8.6%**	**39.1%**	**53.4%**	**52.0%**	**30.5%**	**14.3%**	**-1.4%**	**43.4%**

Non-Irrigated													
	Multi-Use	3,281	2,252	1,652	1,591	87.0%	59.9%	44.1%	42.7%	-27.2%	-15.8%	-1.4%	-44.4%
	Hay/Pasture	165	39	94	198	4.4%	1.0%	2.5%	5.3%	-3.3%	1.5%	2.8%	0.9%
	Totals	**3,447**	**2,292**	**1,746**	**1,789**	**91.4%**	**60.9%**	**46.6%**	**48.0%**	**-30.5%**	**-14.3%**	**1.4%**	**-43.4%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	2.2	1.0	4.8	8.2	0.4	2.7	1.7	7.4	0.5
Max	37.6	30.5	24.7	82.1	82.6	26.2	58.9	7.4	62.8
Average	12.4	9.7	11.3	31.5	16.4	8.3	17.5	7.4	11.0
Sum	74.5	87.2	90.7	189.2	196.3	57.9	87.5	7.4	121.5

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	30.5
Channel to Riparian (acres)	43.2
Riparian Encroachment (acres)	**12.7**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	54.8
1950s Floodplain Mapped as 2011 Channel (Ac)	16.9
Total Recruitment (1950s to 2011)(Ac)	**71.7**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	7.0	25.5	14.4	0.0	**46.9**
Acres/Valley Mile	1.9	7.1	4.0	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	7.95	0.31%	0.70	0.02	1.03	0.19

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	105.0	79.0	20.3%
Rip Rap Margin	94.1	87.4	22.4%
Secondary Channel	28.3	26.7	6.8%
Secondary Channel (Seasonal)	15.3	19.4	5.0%
Channel Crossover	123.0	78.2	20.1%
Side Bar		44.4	11.4%
Mid-channel Bar		6.8	1.7%
Island	23.9	23.9	6.1%
Dry Channel		23.9	6.1%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Custer	**Upstream River Mile**	192.3
Classification	PCM/I: Partially confined meandering/islands	**Downstream River Mile**	185
General Location	to Miles City	**Length**	7.30 mi (11.75 km)
General Comments	to Miles City		

Narrative Summary

Reach C16 is 7.32 miles long and is located just upstream of Miles City. The downstream limit of the reach is the mouth of the Tongue River at RM 185. The reach is characterized by a dominant main thread that shows a distinct meandering pattern, with several islands persisting where meander bends have historically cut off. The river intermittently flows along the valley wall. As a result it is classified as Partially Confined Meandering with Islands (PCM/I).

As of 2011 there were about two miles of armor protecting 14 percent of the total bankline in Reach C16, including 7,000 feet of rock riprap, 2,200 feet of concrete riprap, and 1,550 feet of flow deflectors. All of the concrete armor is protecting urban areas around the water treatment plant in Miles City. The flow deflectors protect non-irrigated agricultural land, and the rock riprap is protecting agricultural land (irrigated and non-irrigated), roads, and the rail line. A ~550 foot-long stretch of armor at RM 190.5R has been flanked since 2001, and erosion behind the armor now threatens a road; the river has locally eroded into the road embankment. There were also several miles of transportation encroachments and floodplain levees mapped in the reach.

About 13 percent (308 acres) of the 100-year floodplain has become isolated from the river in Reach C16, meaning it is no longer inundated at what was historically a 100-year flood event. Isolation can be due to flow changes and/or physical features that block overflows from reaching floodplain areas. Most of the 100-year floodplain isolation (185 acres) is due to the active rail line. Isolation of the 5-year floodplain has been even more substantial, with 62 percent (721 acres) of the historic 5-year floodplain no longer inundated at what was historically a 5-year flood event.

Three ice jams have been reported in the reach, including February of 2011, and March of 2003 and 2012. No damages were recorded in the ice jam database.

At RM 186.6 a steel trestle bridge built for the now abandoned Milwaukee Railroad crosses the river where it is about 1,000 feet wide. There are several very large barbs on the right bank of the river upstream of the bridge that extend about 100 feet off of the bank, and there is riprap directly under the structure.

About 210 acres which represents 9 percent of the total CMZ have become restricted by physical features. Areas that have become restricted to channel migration include the water treatment plant just upstream of the mouth of the Tongue River, behind the railroad grade at RM 191.5, and locally behind stretches of bank armor protecting irrigated and non-irrigated fields.

Mapped land uses in Reach C16 range from agricultural to urban to transportation infrastructure. The total acreage of flood irrigated land in the reach has dropped from 1,000 acres in 1950 to 830 acres in 2001; and during that time about 300 acres were developed for pivot. All of the pivot development occurred prior to 1976. Pivot irrigation has encroached into the active river corridor; approximately 27 acres of pivot-irrigated land is within the natural Channel Migration Zone (CMZ) of the river, making it especially susceptible to threats of river erosion. This pivot is at RM 190R, where a ~300 acre pivot field extends to within 150 feet of the river bank.

Reach C16 shows an increase in forest area considered to be at low risk of cowbird parasitism. In 1950, the reach had 54.5 acres of such forest per valley mile and by 2001 that forest extent had increased to 66.7 acres per valley mile.

A total of 170 acres of Russian olive were mapped in the reach, which is an abrupt increase relative to the two reaches upstream. The Russian olive is distributed throughout the riparian corridor but becomes more prolific in the downstream direction towards Miles City.

Reach C16 was sampled as part of the fisheries study. A total of 32 fish species were sampled in the reach, including Blue Sucker and Sauger, which have been identified as Species of Concern (SOC) by the Montana Natural Heritage Program.

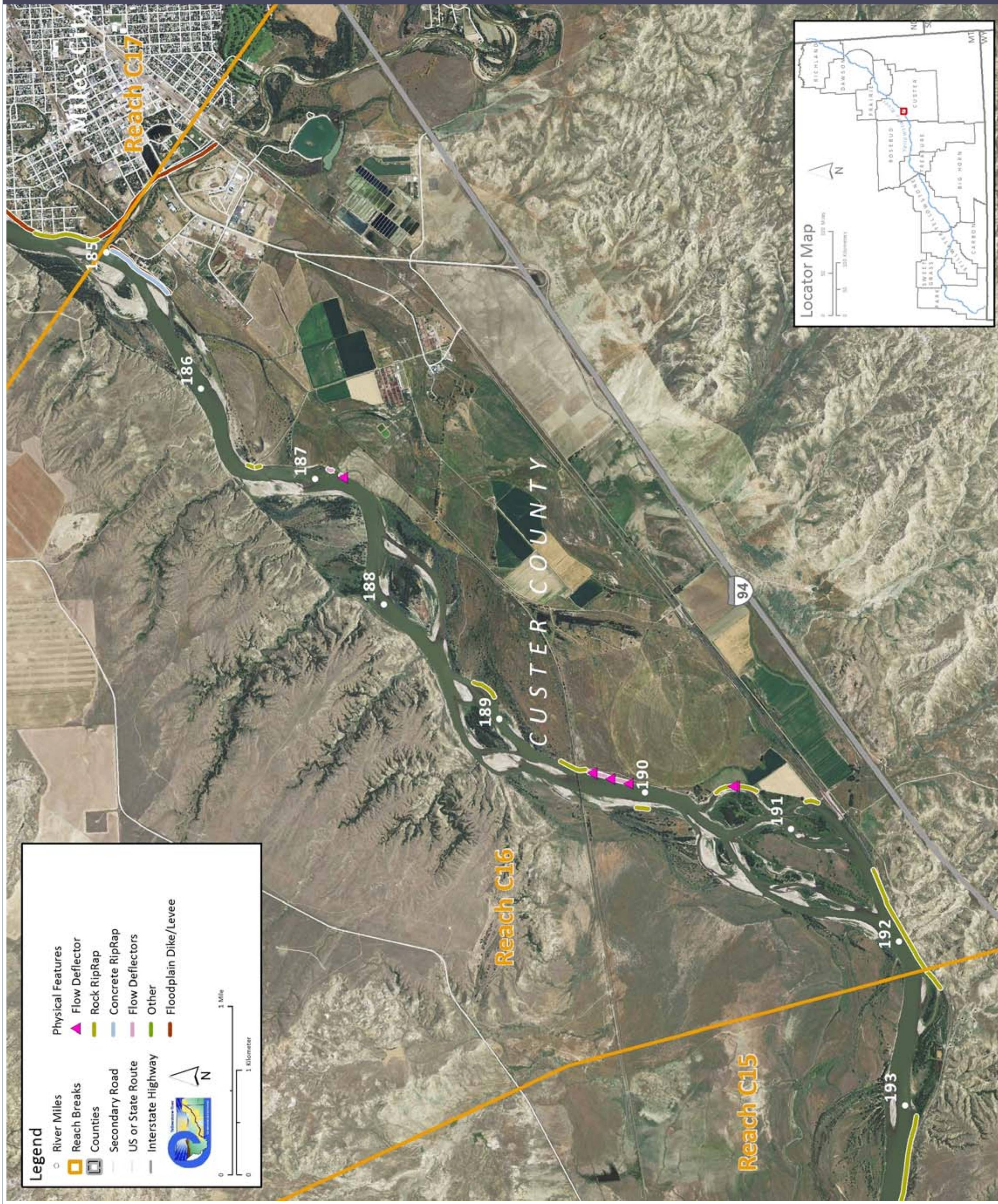
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped by 18 percent and the 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,850 cfs to 3,070 cfs with human development, a reduction of 37 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,340 cfs under unregulated conditions to 3,390 cfs under regulated conditions, a reduction of 47 percent.

Fall and winter base flows have increased in Reach C16 by about 60 percent.

CEA-Related observations in Reach C16 include:
•Pivot irrigation encroachment into CMZ

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C16 include:
•Russian olive removal
•Removal of flanked rock riprap at RM 190.5R to prevent accelerated erosion behind

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	1.0	172.1

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		62,000	77,900	88,100	110,000	120,000	142,000	4,850	6,340
Regulated		47,300	61,700	70,900	90,400	98,500	117,000	3,070	3,390
% Change		-23.71%	-20.80%	-19.52%	-17.82%	-17.92%	-17.61%	-36.70%	-46.53%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	60,700	22,700	6,100
	Regulated	46,900	13,700	4,430
	% Change	**-23%**	**-40%**	**-27%**
Summer	Unregulated	42,800	13,500	6,340
	Regulated	32,600	8,340	3,390
	% Change	**-24%**	**-38%**	**-47%**
Fall	Unregulated	9,150	5,550	2,300
	Regulated	10,500	6,900	3,640
	% Change	**15%**	**24%**	**58%**
Winter	Unregulated	11,700	4,960	2,020
	Regulated	12,400	6,040	3,260
	% Change	**6%**	**22%**	**61%**
Annual	Unregulated	45,500	7,950	2,800
	Regulated	34,200	7,400	3,630
	% Change	**-25%**	**-7%**	**30%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	7/7/96 - 7/10/98	B/W		6295000	39800
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	08/05/2005	color	1-meter pixels	6309000	5620
2005	NAIP	07/08/2005	color	1-meter pixels	6309000	18800
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	6,789	8.9%	7,009	9.2%	221
	Flow Deflectors	601	0.8%	491	0.6%	-110
	Concrete RipRap	2,192	2.9%	2,192	2.9%	0
	Between Flow Deflectors	1,009	1.3%	1,064	1.4%	55
	Feature Type Totals	**10,590**	**13.9%**	**10,756**	**14.1%**	**166**
Floodplain Control						
	Transportation Encroachment	26,981	35.3%	26,981	35.3%	0
	Floodplain Dike/Levee	4,960	6.5%	4,960	6.5%	0
	Feature Type Totals	**31,940**	**41.8%**	**31,940**	**41.8%**	**0**
	Reach Totals	**42,531**	**55.7%**	**42,696**	**55.9%**	**166**

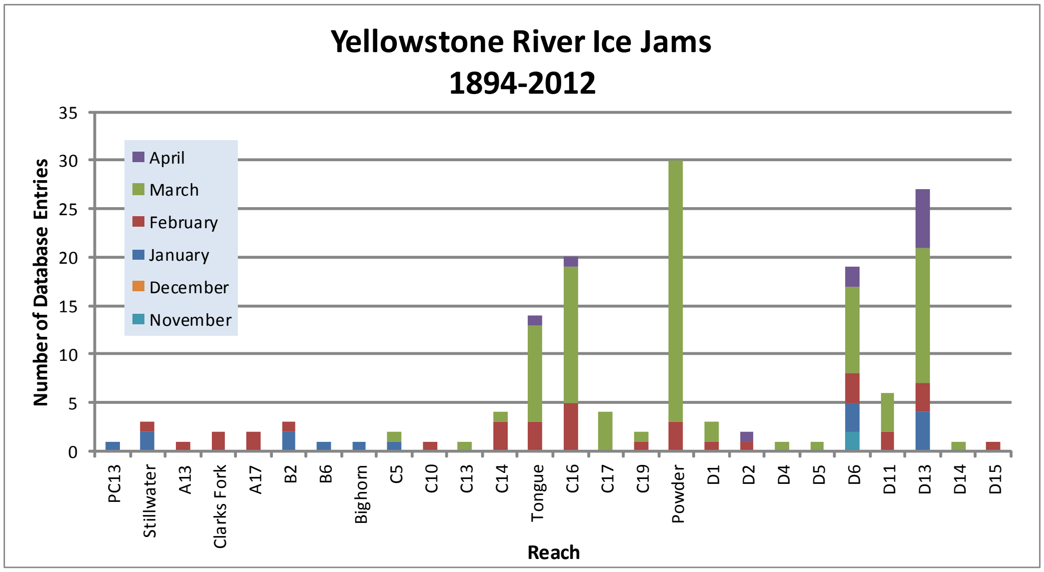
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	0	0	0	0	0	0	2,191	0
Flow Deflectors/Between FDs	0	1,610	0	0	0	0	0	0
Rock RipRap	1,735	380	0	295	0	5,120	0	0
Totals	**1,735**	**1,991**	**0**	**295**	**0**	**5,120**	**2,191**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
3/14/2003	Break-up		?
2/14/2011	Break-up		
3/7/2012	Break-up		

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	38,597	49,582	2.28
1976	38,461	45,055	2.17
1995	38,125	41,208	2.08
2001	38,194	42,010	2.10
Change 1950 - 2001	**-403**	**-7,572**	**-0.18**

	% Change in Braiding
1950 to 1976:	-4.95%
1976 to 1995:	-4.17%
1995 to 2001:	0.92%
1950 to 2001:	-8.08%

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	53	2.2%		
Agriculture (generally relates to field boundaries)	42	1.7%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	14	0.6%		
Railroad	185	7.6%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	13	0.5%		
Total Not Isolated (Ac)	2139		1282	
Total Floodplain Area (Ac)	2447		2003	
Total Isolated (Ac)	**308**	**12.6%**	**721**	**62.0%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	0	**0**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
332	663	2,033	195	10%	214	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	35	1.5%
	Public Road	18	0.8%
	Non-Irrigated	8	0.4%
RipRap			
	Urban Industrial	50	2.2%
	Railroad	7	0.3%
	Non-Irrigated	15	0.7%
	Irrigated	49	2.2%
Flow Deflectors			
	Non-Irrigated	30	1.3%
	Totals	**210**	**9.3%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
38.5	0.0	27.0	21.1	4.9

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	92	158	159	159	1.2%	2.0%	2.1%	2.1%
	Totals	**92**	**158**	**159**	**159**	**1.2%**	**2.0%**	**2.1%**	**2.1%**
Agricultural Land									
	Non-Irrigated	5,180	4,894	4,895	4,877	66.8%	63.1%	63.1%	62.9%
	Irrigated	1,004	1,199	1,131	1,131	12.9%	15.5%	14.6%	14.6%
	Totals	**6,184**	**6,093**	**6,026**	**6,008**	**79.8%**	**78.6%**	**77.7%**	**77.5%**
Channel									
	Channel	1,176	1,111	1,107	1,125	15.2%	14.3%	14.3%	14.5%
	Totals	**1,176**	**1,111**	**1,107**	**1,125**	**15.2%**	**14.3%**	**14.3%**	**14.5%**
ExUrban									
	ExUrban Other	74	0	0	0	1.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	4	4	4	0.0%	0.0%	0.0%	0.0%
	Totals	**74**	**4**	**4**	**4**	**1.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	54	16	10	10	0.7%	0.2%	0.1%	0.1%
	Interstate	0	48	48	48	0.0%	0.6%	0.6%	0.6%
	Railroad	63	63	32	32	0.8%	0.8%	0.4%	0.4%
	Totals	**118**	**128**	**91**	**91**	**1.5%**	**1.6%**	**1.2%**	**1.2%**
Urban									
	Urban Other	102	173	200	200	1.3%	2.2%	2.6%	2.6%
	Urban Residential	0	0	37	37	0.0%	0.0%	0.5%	0.5%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	8	39	39	0.0%	0.1%	0.5%	0.5%
	Urban Industrial	6	78	90	90	0.1%	1.0%	1.2%	1.2%
	Totals	**108**	**259**	**366**	**366**	**1.4%**	**3.3%**	**4.7%**	**4.7%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	304	304	304	0.0%	5.0%	5.0%	5.1%	5.0%	0.1%	0.0%	5.1%
	Flood	1,004	895	827	827	16.2%	14.7%	13.7%	13.8%	-1.5%	-1.0%	0.0%	-2.5%
	Totals	**1,004**	**1,199**	**1,131**	**1,131**	**16.2%**	**19.7%**	**18.8%**	**18.8%**	**3.4%**	**-0.9%**	**0.1%**	**2.6%**

Non-Irrigated													
Multi-Use	3,531	4,643	4,806	4,751	57.1%	76.2%	79.8%	79.1%	19.1%	3.5%	-0.7%	22.0%
Hay/Pasture	1,649	250	89	126	26.7%	4.1%	1.5%	2.1%	-22.6%	-2.6%	0.6%	-24.6%
Totals	**5,180**	**4,894**	**4,895**	**4,877**	**83.8%**	**80.3%**	**81.2%**	**81.2%**	**-3.4%**	**0.9%**	**-0.1%**	**-2.6%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.8	0.3	0.9	0.0	0.8	0.7	6.3	1.7	1.0
Max	84.1	74.1	29.0	61.8	68.9	71.3	62.0	81.1	84.9
Average	10.9	8.7	7.4	15.0	14.3	16.0	18.1	18.8	21.3
Sum	347.5	234.2	177.6	346.1	315.4	336.9	217.2	225.6	320.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	119.9
Channel to Riparian (acres)	174.4
Riparian Encroachment (acres)	**54.5**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	175.1
1950s Floodplain Mapped as 2011 Channel (Ac)	26.8
Total Recruitment (1950s to 2011)(Ac)	**201.9**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	21.2	94.7	23.1	0.0	**139.1**
Acres/Valley Mile	3.2	14.3	3.5	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	170.16	3.72%	41.91	4.03	53.93	17.93

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
✓	✓	Bigmouth buffalo
✓	✓	Black bullhead
✓	✓	Black crappie
✓	✓	Blue sucker
✓	✓	Bluegill
✓	✓	Brook stickleback
	✓	Brown trout
✓	✓	Burbot
		Catfish species
✓	✓	Channel catfish
✓	✓	Common carp
	✓	Creek chub
✓	✓	Emerald shiner
✓	✓	Fathead minnow
✓	✓	Flathead chub
✓	✓	Freshwater drum
✓	✓	Goldeye
✓	✓	Green sunfish
	✓	Lake chub
	✓	Largemouth bass
✓	✓	Longnose dace
✓	✓	Longnose sucker
✓	✓	Minnow species
		Mottled sculpin
✓	✓	Mountain sucker
	✓	Mountain whitefish
	✓	Northern pike
✓	✓	Northern plains killifish
		Northern redbelly dace
		Pallid sturgeon
	✓	Pumpkinseed
		Rainbow trout
✓	✓	River carpsucker
	✓	Rock bass
✓	✓	Sand shiner
✓	✓	Sauger
✓	✓	Shorthead redhorse
		Shortnose gar
✓	✓	Shovelnose sturgeon
		Sicklefin chub
✓	✓	Smallmouth bass
✓	✓	Smallmouth buffalo
✓	✓	Stonecat
		Sturgeon chub
✓	✓	Sucker species
	✓	Sunfish species
	✓	Walleye
✓	✓	Western silvery minnow
		White bass
✓	✓	White crappie
✓	✓	White sucker
	✓	Yellow bullhead
		Yellow perch

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	234.3	102.3	9.2%
Rip Rap Bottom	58.7	44.9	4.1%
Rip Rap Margin	52.3	47.5	4.3%
Bluff Pool	97.8	86.3	7.8%
Terrace Pool	6.8		
Secondary Channel	88.3	114.0	10.3%
Secondary Channel (Seasonal)	109.6	87.6	7.9%
Channel Crossover	187.8	120.1	10.9%
Point Bar		24.5	2.2%
Side Bar		59.4	5.4%
Mid-channel Bar		59.1	5.3%
Island	269.2	266.2	24.1%
Dry Channel		93.1	8.4%
Confluence Area	1.6	1.6	0.1%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Custer	**Upstream River Mile**	185
Classification	PCS: Partially confined straight	**Downstream River Mile**	180.5
General Location	Miles City; Tongue River confluence	**Length**	4.50 mi (7.24 km)
General Comments	Miles City; Tongue River		

Narrative Summary

Reach C17 is 4.5 miles long and is in Miles City. Through town the Yellowstone River is a Partially Confined Reach type as the river flows on the north edge of town against high bluffs of the Fort Union Formation.

As of 2011 there were just under two miles of armor protecting 21 percent of the total bankline in Reach C17, including 7,300 feet of rock riprap, 2,400 feet of concrete riprap, and less than a hundred feet of flow deflectors. Over 2,700 feet of rock riprap has been constructed in the reach since 2001. Most of the armor is on the right bank through town. The rock riprap is protecting either urban areas (2,540 feet) the railroad (2,040 feet), or agricultural lands (2,400 feet). The concrete riprap is all protecting agricultural land. Reach C17 also has over three miles of mapped floodplain dikes and levees, much of which is the Miles City Levee that is on the right bank of the river through town.

Prior to 1950, about 1,500 feet of side channel was blocked in Reach C17. This channel was actually the lowermost part of the Tongue River, which was re-routed to the Yellowstone and abandoned through what is now Miles City.

Ice jams have been a major issue in Miles City. The ice jam database records 24 ice jams in Reach C17 between 1934 and 2011. Most of the jams occurred in March, with a few in February and one in April in 1950. Damages associated with the jams include damages to the Miles City dike, damaged water gages, flooding, and evacuations.

The levees in Miles City coupled with flow alterations have isolated 683 acres, or 74 percent of the 100-year floodplain in the reach. Isolation of the 5-year floodplain has been similar; 286 acres or 78 percent of the 5-year floodplain has become isolated at that frequency event. Most of the 5-year floodplain isolation is along the historic Tongue River channel that has been cut off from the river.

Bank armor and levees on the south side of the river has narrowed the natural Channel Migration Zone of the river. About 540 acres which represents 40 percent of the total CMZ has become restricted by physical features.

One dump site was mapped on the right bank just below the Highway 59 Bridge at RM 184.

As an urban reach, the riparian corridor had already been largely impacted by 1950. Since then, however, almost 100 acres of additional riparian area has been cleared, representing 23 percent of the entire 1950s riparian footprint. With this clearing, the reach has seen a substantial loss of forest area considered at low risk of cowbird parasitism. In 1950, the reach had 9.1 acres of such forest per valley mile and by 2001 that forest extent had dropped to 0 acres per valley mile.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped by 19 percent and the 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 5,100 cfs to 3,180 cfs with human development, a reduction of 37 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,730 cfs under unregulated conditions to 3,530 cfs under regulated cond8itions, a reduction of 48 percent.

Fall and winter base flows have increased in Reach C17 by about 60 percent.

CEA-Related observations in Reach C17 include:
•Side channel blockage with urbanization
•Extensive armoring with urbanization

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C17 include:
•CMZ Management due to extent of CMZ restriction (41 percent)
•Dump removal on right bank at RM 184R
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	149.7	-1.0

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		63,400	78,900	88,600	109,000	117,000	136,000	5,100	6,730
Regulated		48,200	62,700	71,300	88,000	94,400	108,000	3,180	3,530
% Change		-23.97%	-20.53%	-19.53%	-19.27%	-19.32%	-20.59%	-37.65%	-47.55%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	62,000	23,300	6,430
	Regulated	47,800	13,900	4,640
	% Change	**-23%**	**-40%**	**-28%**
Summer	Unregulated	44,200	14,000	6,730
	Regulated	33,300	8,550	3,530
	% Change	**-25%**	**-39%**	**-48%**
Fall	Unregulated	9,390	5,740	2,340
	Regulated	10,800	7,100	3,750
	% Change	**15%**	**24%**	**60%**
Winter	Unregulated	12,400	5,170	2,080
	Regulated	13,100	6,240	3,330
	% Change	**6%**	**21%**	**60%**
Annual	Unregulated	46,700	8,300	2,870
	Regulated	34,900	7,640	3,740
	% Change	**-25%**	**-8%**	**30%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	8/25/97 - 7/10/98	B/W		6309000	15400
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6309000	3500
2005	NAIP	08/05/2005	color	1-meter pixels	6309000	5620
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	4,580	9.7%	7,294	15.5%	2,714
	Flow Deflectors	0	0.0%	92	0.2%	92
	Concrete RipRap	2,401	5.1%	2,398	5.1%	-3
	Feature Type Totals	**6,981**	**14.8%**	**9,784**	**20.8%**	**2,803**
Floodplain Control						
	Transportation Encroachment	4,563	9.7%	4,563	9.7%	0
	Floodplain Dike/Levee	19,101	40.6%	19,101	40.6%	0
	Feature Type Totals	**23,664**	**50.3%**	**23,664**	**50.3%**	**0**
	Reach Totals	**30,645**	**65.2%**	**33,448**	**71.1%**	**2,803**

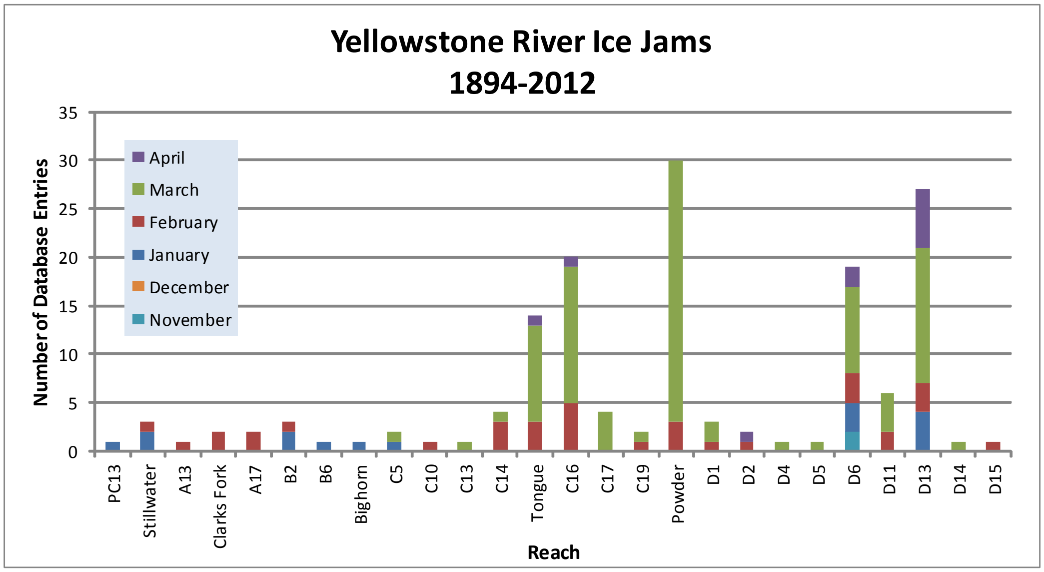
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	833	954	610	0	0	0	0	0
Rock RipRap	0	0	0	0	0	2,040	2,539	0
Totals	**833**	**954**	**610**	**0**	**0**	**2,040**	**2,539**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
3/10/1934	NA	184	?
3/22/1939	NA	184	?
3/23/1941	NA	184	?
3/26/1943	NA	184	?
3/20/1944	NA	184	Flooding and evacuations
3/2/1946	Break-up	184	?
3/20/1947	Break-up	184	?
3/26/1949	NA	184	?
4/6/1950	NA	184	?
3/26/1951	NA	184	?
3/26/1956	NA	184	?
2/21/1958	NA	184	?
3/13/1959	NA	184	?
3/19/1960	NA	184	?
2/17/1962	NA	184	?
2/1/1971	Break-up	184	Levee threatened by erosion
3/1/1972	Break-up	184	Dike damage
3/8/1994	NA	184	Miles City dike damaged
2/8/1996	Break-up	184	Damaged water gauges
2/18/1997	NA	184	Flooding in low-lands, dike damaged
3/5/2009	Break-up		
3/16/2010	Break-up		
3/12/2011	Break-up		
3/13/2011			

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	23,304	16,353	1.70	1950 to 1976:	7.47%
1976	23,247	19,269	1.83	1976 to 1995:	-4.93%
1995	23,408	17,291	1.74	1995 to 2001:	-2.59%
2001	23,507	16,305	1.69	1950 to 2001:	-0.48%
Change 1950 - 2001	**202**	**-48**	**-0.01**		

Length of Side Channels Blocked

Pre-1950s (ft)	1,466
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	47	5.1%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	636	69.1%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	237		529	
Total Floodplain Area (Ac)	919		788	
Total Isolated (Ac)	**683**	**74.3%**	**259**	**77.9%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	0	**0**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
145	291	930	146	16%	407	394	97%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Irrigated	58	4.3%
Dike/Levee			
	Urban Residential	482	35.9%
	Totals	**540**	**40.3%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
64.1	0.0	0.0	294.4	2.6

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	31	60	63	65	0.8%	1.5%	1.6%	1.6%
	Totals	**31**	**60**	**63**	**65**	**0.8%**	**1.5%**	**1.6%**	**1.6%**
Agricultural Land									
	Non-Irrigated	1,186	1,056	983	930	29.3%	26.1%	24.3%	23.0%
	Irrigated	825	705	655	609	20.4%	17.4%	16.2%	15.0%
	Totals	**2,011**	**1,762**	**1,638**	**1,539**	**49.7%**	**43.5%**	**40.5%**	**38.0%**
Channel									
	Channel	713	710	691	694	17.6%	17.5%	17.1%	17.1%
	Totals	**713**	**710**	**691**	**694**	**17.6%**	**17.5%**	**17.1%**	**17.1%**
ExUrban									
	ExUrban Other	0	0	23	23	0.0%	0.0%	0.6%	0.6%
	ExUrban Undeveloped	0	0	7	7	0.0%	0.0%	0.2%	0.2%
	ExUrban Industrial	0	38	87	87	0.0%	0.9%	2.1%	2.1%
	ExUrban Commercial	16	16	17	17	0.4%	0.4%	0.4%	0.4%
	ExUrban Residential	15	212	250	344	0.4%	5.2%	6.2%	8.5%
	Totals	**30**	**266**	**384**	**477**	**0.7%**	**6.6%**	**9.5%**	**11.8%**
Transportation									
	Public Road	35	36	36	36	0.9%	0.9%	0.9%	0.9%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	52	52	25	25	1.3%	1.3%	0.6%	0.6%
	Totals	**87**	**87**	**61**	**61**	**2.1%**	**2.2%**	**1.5%**	**1.5%**
Urban									
	Urban Other	19	19	51	51	0.5%	0.5%	1.2%	1.2%
	Urban Residential	738	719	767	767	18.2%	17.8%	18.9%	18.9%
	Urban Commercial	164	164	165	165	4.0%	4.0%	4.1%	4.1%
	Urban Undeveloped	129	31	0	0	3.2%	0.8%	0.0%	0.0%
	Urban Industrial	128	233	230	230	3.2%	5.7%	5.7%	5.7%
	Totals	**1,177**	**1,165**	**1,212**	**1,212**	**29.1%**	**28.8%**	**29.9%**	**29.9%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	825	705	655	609	41.0%	40.0%	40.0%	39.6%	-1.0%	0.0%	-0.4%	-1.4%
	Totals	**825**	**705**	**655**	**609**	**41.0%**	**40.0%**	**40.0%**	**39.6%**	**-1.0%**	**0.0%**	**-0.4%**	**-1.4%**

Non-Irrigated

Multi-Use	1,139	935	873	781	56.6%	53.1%	53.3%	50.8%	-3.5%	0.2%	-2.5%	-5.9%
Hay/Pasture	47	121	111	149	2.4%	6.9%	6.7%	9.7%	4.5%	-0.1%	2.9%	7.3%
Totals	**1,186**	**1,056**	**983**	**930**	**59.0%**	**60.0%**	**60.0%**	**60.4%**	**1.0%**	**0.0%**	**0.4%**	**1.4%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	1.0	0.0	0.0	1.2	0.2	0.3	4.5	3.2	3.2
Max	14.7	13.0	10.4	83.0	49.5	38.0	90.5	76.8	66.6
Average	5.4	4.0	4.3	20.5	11.5	13.1	34.7	20.5	19.8
Sum	27.2	36.4	25.8	225.5	173.0	221.9	173.3	122.8	119.0

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	19.0
Channel to Riparian (acres)	69.1
Riparian Encroachment (acres)	**50.1**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	69.7
1950s Floodplain Mapped as 2011 Channel (Ac)	8.7
Total Recruitment (1950s to 2011)(Ac)	**78.4**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	18.5	48.4	0.7	0.0	**67.6**
Acres/Valley Mile	4.6	12.0	0.2	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	66.49	2.63%	26.91	12.61	19.55	20.45

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	37.2	34.2	4.9%
Rip Rap Bottom	44.9	28.3	4.1%
Bluff Pool	196.2	173.0	25.0%
Secondary Channel	13.0	15.0	2.2%
Secondary Channel (Seasonal)	59.9	30.8	4.5%
Channel Crossover	102.2	91.2	13.2%
Point Bar		2.3	0.3%
Side Bar		29.7	4.3%
Mid-channel Bar		25.4	3.7%
Island	236.6	236.6	34.2%
Dry Channel		23.4	3.4%
Confluence Area	1.0	1.0	0.1%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.

There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Custer	**Upstream River Mile**	180.5
Classification	PCS: Partially confined straight	**Downstream River Mile**	177.3
General Location	Downstream of Miles City	**Length**	3.20 mi (5.15 km)
General Comments	Channel follows left valley wall		

Narrative Summary

Reach C18 is 3.2 miles long and is located just downstream of Miles City. It is a Partially Confined Straight reach type, as the river flows over steep bedrock shelves that create a series of rapids between Miles City and a few miles above Kinsey Bridge. The river flows along the north bluff line through the whole reach, and has consistently maintained this course since at least 1950.

Reach C18 has no mapped bank armor which is indicative of the natural stability provided to this reach by erosion-resistant bedrock. The 2001 physical features inventory identified 1,742 feet of bedrock outcrop in the reach. A total of three discreet sets of rapids were mapped in the reach, all of which have been described as part of the Buffalo Shoals (RM 180, RM 179.9, and RM 178.2).

Between 1950 and 2001 there was about 26 net acres of riparian encroachment into the channel, and the bankfull channel area decreased by ~30 acres, indicating a diminishing river size over the last half-century. This trend is common below the mouth of the Bighorn River, where flow alterations have reduced peak flows and cause the active river channel to shrink. Consumptive water uses, primarily associated with irrigation, have contributed to the reduced flows.

Prior to 1950, a side channel that was just over 1,000 feet long appears to have been blocked at RM 179. There are currently several blockages across this old channel, including two roads that access a large gravel pit on the right bank of the river. This gravel pit at RM 178.4 is partly within the Channel Migration Zone (CMZ) of the river. Although the channel showed clear expression in the 1950s imagery, it is not very visible in the 2011 imagery, suggesting that restoring this feature may be difficult.

About 20 percent of the total 100-year floodplain has become isolated due to human development, and most of the isolation appears to be due to flow alterations rather than floodplain dikes. The 5-year floodplain is even more affected; 59 percent of the historic 5-year floodplain is no longer inundated at that frequency.

Land use is dominated by flood irrigation with additional gravel pit development (mapped as exurban industrial) and transportation infrastructure. There is one Fishing Access Site at Kinsey Bridge. There are two animal handling facilities north of the river that are within several hundred feet of the streambank; both are downstream of Kinsey Bridge, at RM 166.2 and RM 167.8.

There are 65 acres of Russian olive in the reach, most of which is on the south side of the river away from the bluff line to the north. Over half of the low-flow fish habitat in this reach is bluff pool, potentially making it important for fish with bluff pool habitat preferences.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped by 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 5,100 cfs to 3,180 cfs with human development, a reduction of 38 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,730 cfs under unregulated conditions to 3,530 cfs under regulated conditions, a reduction of 48 percent.

CEA-Related observations in Reach C18 include:
•Natural channel stability provided by bedrock
•Minimal bank armoring

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C18 include:
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	146.5	3.5

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		63,400	78,900	88,600	109,000	117,000	136,000	5,100	6,730
Regulated		48,200	62,700	71,300	88,000	94,400	108,000	3,180	3,530
% Change		-23.97%	-20.53%	-19.53%	-19.27%	-19.32%	-20.59%	-37.65%	-47.55%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	62,000	23,300	6,430
	Regulated	47,800	13,900	4,640
	% Change	**-23%**	**-40%**	**-28%**
Summer	Unregulated	44,200	14,000	6,730
	Regulated	33,300	8,550	3,530
	% Change	**-25%**	**-39%**	**-48%**
Fall	Unregulated	9,390	5,740	2,340
	Regulated	10,800	7,100	3,750
	% Change	**15%**	**24%**	**60%**
Winter	Unregulated	12,400	5,170	2,080
	Regulated	13,100	6,240	3,330
	% Change	**6%**	**21%**	**60%**
Annual	Unregulated	46,700	8,300	2,870
	Regulated	34,900	7,640	3,740
	% Change	**-25%**	**-8%**	**30%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	8/25/97 - 6/13/96	B/W		6309000	15400
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6309000	3500
2005	NAIP	08/05/2005	color	1-meter pixels	6309000	5620
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

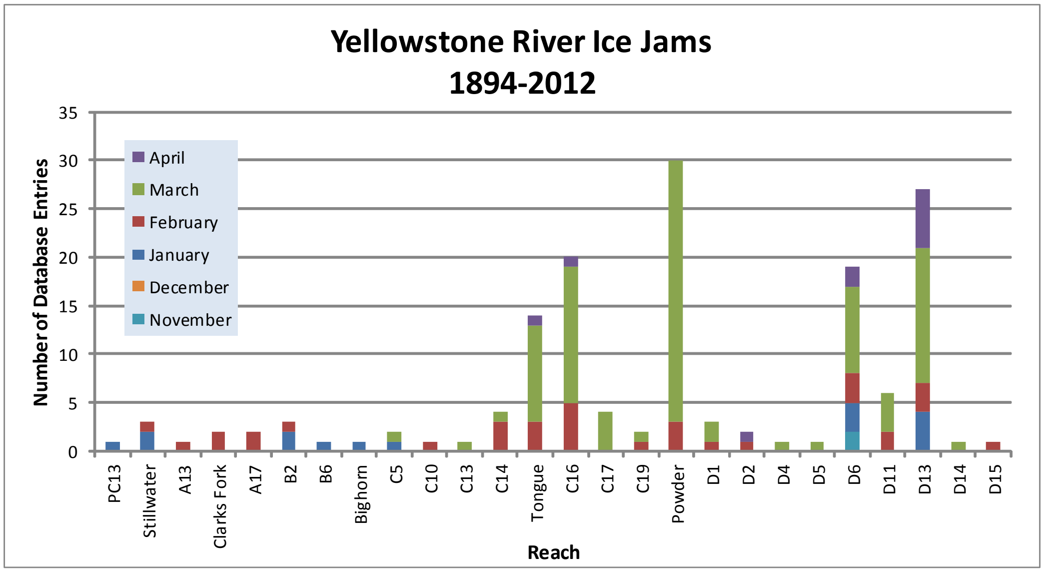
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Other In Channel						
	Bedrock Outcrop	1,742	5.1%	1,742	5.1%	0
	Feature Type Totals	**1,742**	**5.1%**	**1,742**	**5.1%**	**0**
	Reach Totals	**1,742**	**5.1%**	**1,742**	**5.1%**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	16,929		1.00	1950 to 1976:	0.00%
1976	17,030		1.00	1976 to 1995:	27.63%
1995	17,048	4,711	1.28	1995 to 2001:	-21.65%
2001	17,106		1.00	1950 to 2001:	0.00%
Change 1950 - 2001	**177**		**0.00**		

Length of Side Channels Blocked

Pre-1950s (ft)	1,052
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	59	20.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	237		390	
Total Floodplain Area (Ac)	297		457	
Total Isolated (Ac)	**59**	**20.0%**	**67**	**59.5%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	0	**0**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
118	236	466	1	0%	45	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Irrigated	1	0.3%
	Totals	**1**	**0.3%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
2.8	0.0	0.0	6.9	0.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	29	55	81	85	1.1%	2.0%	2.9%	3.1%
	Totals	**29**	**55**	**81**	**85**	**1.1%**	**2.0%**	**2.9%**	**3.1%**
Agricultural Land									
	Non-Irrigated	1,071	938	924	985	38.5%	33.7%	33.2%	35.4%
	Irrigated	1,319	1,369	1,370	1,305	47.4%	49.2%	49.3%	46.9%
	Totals	**2,391**	**2,307**	**2,294**	**2,290**	**86.0%**	**82.9%**	**82.5%**	**82.3%**
Channel									
	Channel	336	362	354	349	12.1%	13.0%	12.7%	12.5%
	Totals	**336**	**362**	**354**	**349**	**12.1%**	**13.0%**	**12.7%**	**12.5%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	18	18	23	0.0%	0.6%	0.6%	0.8%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	4	18	18	18	0.1%	0.7%	0.7%	0.7%
	Totals	**4**	**36**	**36**	**42**	**0.1%**	**1.3%**	**1.3%**	**1.5%**
Transportation									
	Public Road	12	12	12	12	0.4%	0.4%	0.4%	0.4%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	9	9	4	4	0.3%	0.3%	0.2%	0.2%
	Totals	**21**	**21**	**16**	**16**	**0.8%**	**0.8%**	**0.6%**	**0.6%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	1,319	1,369	1,370	1,305	55.2%	59.3%	59.7%	57.0%	4.2%	0.4%	-2.7%	1.8%
	Totals	**1,319**	**1,369**	**1,370**	**1,305**	**55.2%**	**59.3%**	**59.7%**	**57.0%**	**4.2%**	**0.4%**	**-2.7%**	**1.8%**

Non-Irrigated													
	Multi-Use	1,071	933	914	930	44.8%	40.4%	39.8%	40.6%	-4.4%	-0.6%	0.8%	-4.2%
	Hay/Pasture	0	5	10	55	0.0%	0.2%	0.4%	2.4%	0.2%	0.2%	2.0%	2.4%
	Totals	**1,071**	**938**	**924**	**985**	**44.8%**	**40.7%**	**40.3%**	**43.0%**	**-4.2%**	**-0.4%**	**2.7%**	**-1.8%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.5	0.2	0.4	0.6	0.8	1.2	10.8	11.8	8.1
Max	15.4	29.8	30.9	205.1	75.1	38.5	10.8	12.4	18.4
Average	7.7	8.2	12.5	69.1	12.9	13.3	10.8	12.1	12.7
Sum	54.0	73.7	87.3	207.2	102.8	119.5	10.8	24.2	38.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	14.0
Channel to Riparian (acres)	40.0
Riparian Encroachment (acres)	**26.0**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	40.4
1950s Floodplain Mapped as 2011 Channel (Ac)	16.8
Total Recruitment (1950s to 2011)(Ac)	**57.2**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	5.7	21.8	0.0	0.0	**27.5**
Acres/Valley Mile	1.8	7.0	0.0	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	65.37	5.05%	23.84	0.00	12.16	1.29

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	**Bankfull**	**Low Flow**	**% of Low Flow**
Scour Pool	41.4	24.1	6.8%
Bluff Pool	262.4	186.4	52.7%
Secondary Channel (Seasonal)	13.9	10.8	3.1%
Channel Crossover	24.7	45.7	12.9%
Point Bar		13.9	3.9%
Side Bar		40.9	11.6%
Mid-channel Bar		0.4	0.1%
Island	11.1	11.1	3.1%
Dry Channel		20.3	5.7%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.

There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Custer	**Upstream River Mile**	177.3
Classification	CS: Confined straight	**Downstream River Mile**	166.2
General Location	Kinsey Bridge	**Length**	11.10 mi (17.86 km)
General Comments	Confined		

Narrative Summary

Reach C19 is 11.1 miles long and is located downstream of Miles City at Kinsey Bridge. It is a Confined Straight reach type, as the river flows over steep bedrock shelves that create a series of rapids between Miles City and a few miles below Kinsey Bridge.

There are approximately 4,000 feet of rock riprap in the reach, about one third of which was built since 2001. All of the armor is protecting the rail line on the south side of the river. By 1950 over three miles of side channels had been blocked off by small floodplain dikes in Reach C19. These old side channels are on both sides of the river just upstream of Kinsey Bridge. Bank migration rates are very low in the reach, and as a result the Channel Migration Zone (CMZ) is unusually narrow.

The Kinsey Main Canal diversion and pump station are located on the left bank at RM 175. The site consists of a rock diversion that extends about 200 feet into the river at an upstream angle to deflect flows into an excavated approach channel and pumping station. Kinsey Bridge is located at RM 172.1 and consists of a Steel multi-beam structure that was built in 1907 for the Milwaukee Railroad, but now supports County Road 62. It is just over 1,000 feet long and has four spans.

The 2001 physical features inventory also identified 7,200 feet of bedrock outcrop in the reach. A total of five discreet sets of rapids were mapped in the reach, including Buffalo Shoals (RM 176 and RM 177), Matthew Rapids (RM 174.5), and two unnamed rapids upstream and downstream of Kinsey Bridge at RM 172.5 and RM 171, respectively.

On the downstream end of the reach, an 8-inch Cenex pipeline that carries petroleum products flows parallel to the river on the landward side of the active BNSF rail line. The pipeline is about 400 feet away from the active riverbank at RM 166.5, but the fact that the rail line sits between the pipeline and the river suggests that its risk of exposure is low.

Between 1950 and 2001 there was about 89 net acres of riparian encroachment into the channel, and the bankfull channel area decreased by ~100 acres, indicating a diminishing river size over the last half-century. This trend is common below the mouth of the Bighorn River, where flow alterations have reduced peak flows and cause the active river channel to shrink. Consumptive water uses, primarily associated with irrigation, have contributed to the reduced flows.

About 13 percent of the total 100-year floodplain has become isolated due to human development, and most of the isolation appears to be due to flow alterations rather than floodplain dikes. The 5-year floodplain is even more affected; 55 percent of the historic 5-year floodplain is no longer inundated at that frequency.

Two ice jams have been reported in Reach C19; one in March of 1994 at RM 168 and the other in February of 1997 at RM 174. No damages were reported.

Land use is dominated by agriculture (~4,700 acres), with 326 acres of pivot irrigation development since 1950. There is one Fishing Access Site at Kinsey Bridge. There are two animal handling facilities north of the river that are within several hundred feet of the streambank; both are downstream of Kinsey Bridge, at RM 166.2 and RM 167.8.

There are 254 acres of Russian olive in the reach, most of which is on the north side of the river away from the bluff line to the south. Russian olive comprises almost 30 percent of all of the mapped shrubs in the reach. There are notably high concentrations of Russian olive in one of the abandoned side channels that is located on the left bank just downstream from the Kinsey Main Canal diversion.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 5,080 cfs to 3,150 cfs with human development, a reduction of 38 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,740 cfs under unregulated conditions to 3,510 cfs under regulated conditions, a reduction of 48 percent.

CEA-Related observations in Reach C19 include:
•Side channel blockages pre-1950
•Russian olive colonization, especially in blocked side channels
•Armoring needs by the railroad on the south bluff line
•Low natural rates of bank movement in reach with extensive bedrock exposure and rapids

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C19 include:
•Side channel reactivation at RM 175L and RM 174R
•Russian olive removal
•Nutrient management at animal handling facilities at RM 166.2L and RM 167.8L

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	135.4	6.7

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		63,700	79,500	89,400	110,000	119,000	138,000	5,080	6,740
Regulated		48,500	63,300	72,100	89,400	96,100	110,000	3,150	3,510
% Change		-23.86%	-20.38%	-19.35%	-18.73%	-19.24%	-20.29%	-37.99%	-47.92%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	62,300	23,400	6,460
	Regulated	48,000	14,000	4,660
	% Change	**-23%**	**-40%**	**-28%**
Summer	Unregulated	44,400	14,000	6,740
	Regulated	33,400	8,570	3,510
	% Change	**-25%**	**-39%**	**-48%**
Fall	Unregulated	9,410	5,750	2,320
	Regulated	10,800	7,120	3,740
	% Change	**15%**	**24%**	**61%**
Winter	Unregulated	12,500	5,180	2,080
	Regulated	13,200	6,250	3,340
	% Change	**6%**	**21%**	**61%**
Annual	Unregulated	46,900	8,330	2,870
	Regulated	35,000	7,660	3,740
	% Change	**-25%**	**-8%**	**30%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	8/1/96 - 8/25/97	B/W		6309000	15400
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6309000	3500
2005	NAIP	08/05/2005	color	1-meter pixels	6309000	5620
2005	NAIP	08/04/2005	color	1-meter pixels	6309000	5550
2005	NAIP	07/08/2005	color	1-meter pixels	6309000	18800
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	2,569	2.2%	4,043	3.4%	1,475
	Feature Type Totals	**2,569**	**2.2%**	**4,043**	**3.4%**	**1,475**
Other In Channel						
	Bedrock Outcrop	7,237	6.2%	7,237	6.2%	0
	Feature Type Totals	**7,237**	**6.2%**	**7,237**	**6.2%**	**0**
	Reach Totals	**9,806**	**8.3%**	**11,280**	**9.6%**	**1,475**

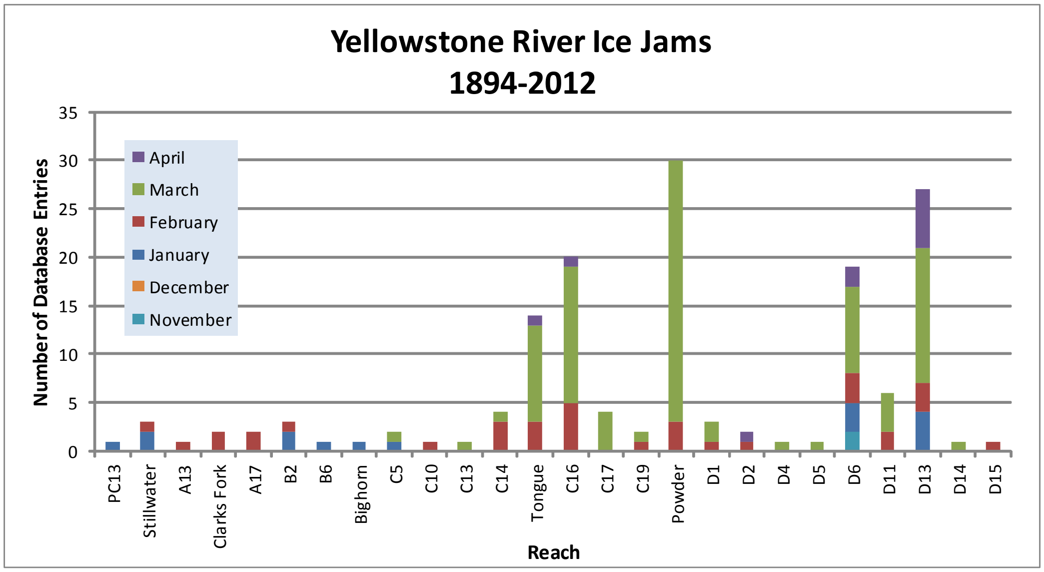
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	0	0	0	0	0	2,568	0	0
Totals	**0**	**0**	**0**	**0**	**0**	**2,568**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
3/5/1994	NA	168	?
2/19/1997	NA	174	?

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	58,436	4,394	1.08
1976	58,444	7,142	1.12
1995	58,737	7,818	1.13
2001	58,737	11,656	1.20
Change 1950 - 2001	**301**	**7,262**	**0.12**

	% Change in Braiding
1950 to 1976:	4.37%
1976 to 1995:	0.97%
1995 to 2001:	5.77%
1950 to 2001:	11.46%

Length of Side Channels Blocked

Pre-1950s (ft)	17,355
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	86	13.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	573		1254	
Total Floodplain Area (Ac)	659		1370	
Total Isolated (Ac)	**86**	**13.0%**	**116**	**54.7%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	0	**0**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
93	186	1,670	3	0%	467	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	3	0.1%
	Totals	**3**	**0.1%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
53.5	0.0	0.0	1.8	5.1

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	179	283	371	363	1.6%	2.5%	3.2%	3.2%
	Totals	**179**	**283**	**371**	**363**	**1.6%**	**2.5%**	**3.2%**	**3.2%**
Agricultural Land									
	Non-Irrigated	5,367	5,300	5,058	5,141	47.0%	46.4%	44.3%	45.0%
	Irrigated	4,385	4,374	4,544	4,451	38.4%	38.3%	39.8%	38.9%
	Totals	**9,753**	**9,674**	**9,601**	**9,592**	**85.3%**	**84.7%**	**84.0%**	**83.9%**
Channel									
	Channel	1,284	1,242	1,193	1,210	11.2%	10.9%	10.4%	10.6%
	Totals	**1,284**	**1,242**	**1,193**	**1,210**	**11.2%**	**10.9%**	**10.4%**	**10.6%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	12	12	0.0%	0.0%	0.1%	0.1%
	Totals	**0**	**0**	**12**	**12**	**0.0%**	**0.0%**	**0.1%**	**0.1%**
Transportation									
	Public Road	84	100	131	131	0.7%	0.9%	1.1%	1.1%
	Interstate	0	0	56	56	0.0%	0.0%	0.5%	0.5%
	Railroad	129	129	65	65	1.1%	1.1%	0.6%	0.6%
	Totals	**213**	**229**	**252**	**252**	**1.9%**	**2.0%**	**2.2%**	**2.2%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	171	326	0.0%	0.0%	1.8%	3.4%	0.0%	1.8%	1.6%	3.4%
	Flood	4,385	4,374	4,373	4,125	45.0%	45.2%	45.5%	43.0%	0.2%	0.3%	-2.5%	-2.0%
	Totals	**4,385**	**4,374**	**4,544**	**4,451**	**45.0%**	**45.2%**	**47.3%**	**46.4%**	**0.2%**	**2.1%**	**-0.9%**	**1.4%**

Non-Irrigated

Multi-Use	4,461	5,138	4,972	5,026	45.7%	53.1%	51.8%	52.4%	7.4%	-1.3%	0.6%	6.7%
Hay/Pasture	906	162	85	115	9.3%	1.7%	0.9%	1.2%	-7.6%	-0.8%	0.3%	-8.1%
Totals	**5,367**	**5,300**	**5,058**	**5,141**	**55.0%**	**54.8%**	**52.7%**	**53.6%**	**-0.2%**	**-2.1%**	**0.9%**	**-1.4%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.0	0.5	0.9	1.2	0.9	0.5	0.7	1.2	2.3
Max	85.1	143.2	157.7	57.0	12.1	10.7	51.6	20.4	11.4
Average	11.7	14.8	16.9	23.2	5.1	3.9	11.1	5.0	6.8
Sum	408.9	489.7	573.5	139.5	56.1	78.8	165.9	55.2	61.4

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	17.9
Channel to Riparian (acres)	106.8
Riparian Encroachment (acres)	**88.9**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	159.2
1950s Floodplain Mapped as 2011 Channel (Ac)	22.6
Total Recruitment (1950s to 2011)(Ac)	**181.8**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	16.1	165.2	12.2	0.0	**193.5**
Acres/Valley Mile	1.5	15.4	1.1	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	254.13	4.98%	128.46	0.73	24.24	1.27

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	381.7	350.0	29.3%
Rip Rap Margin	109.0	97.2	8.1%
Bluff Pool	212.0	144.5	12.1%
Secondary Channel	25.2	25.2	2.1%
Secondary Channel (Seasonal)	50.1	49.1	4.1%
Channel Crossover	376.7	265.0	22.2%
Point Bar		50.5	4.2%
Side Bar		100.2	8.4%
Mid-channel Bar		31.2	2.6%
Island	38.1	38.1	3.2%
Dry Channel		41.8	3.5%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Custer	**Upstream River Mile**	166.2
Classification	CS: Confined straight	**Downstream River Mile**	158.7
General Location	Shirley	**Length**	7.50 mi (12.07 km)
General Comments	Confined		

Narrative Summary

Reach C20 is 7.5 miles long and is located in lowermost Custer County at Shirley. The Bonfield Fishing Access Site is located at RM 161 on the left bank. It is a Confined Straight reach type, as the river flows through the confining geology of the Fort Union Formation sandstones. Small tributaries that enter Reach C20 include Hay Creek (RM 165), Harris Creek (RM 164), Cabin and Cottonwood Creeks (RM 162) and Saugus Creek (RM 160.2). Bank migration rates are very low in the reach, and as a result the Channel Migration Zone (CMZ) is unusually narrow.

There is just over a mile of bank armor in the reach that covers about 8 percent of the total bankline. As of 2011 there was 6,059 feet of rock riprap in reach C20, and 1,650 feet of that armor was built between 2001 and 2011. Most of the rock riprap is protecting the abandoned Milwaukee Rail line on the north side of the river where it runs in the edge of the bluff line. The new armor is protecting the Shirley Pump Station at RM 165.3R. There are also 131 feet of flow deflectors across the river from the Bonfield Fishing Access Site.

Between 1950 and 2001 there was about 50 net acres of riparian encroachment into the channel, and the bankfull channel area decreased by ~58 acres, indicating a diminishing river size over the last half-century. This trend is common below the mouth of the Bighorn River, where flow alterations have reduced peak flows and cause the active river channel to shrink. Consumptive water uses, primarily associated with irrigation, have contributed to the reduced flows.

About 13 percent of the total 100-year floodplain has become isolated due to human development, and most of the isolation appears to be due to flow alterations rather than floodplain dikes. The 5-year floodplain is even more affected; 55 percent of the historic 5-year floodplain is no longer inundated at that frequency.

Land use is dominated by agriculture (~6,200 acres), with 327 acres of pivot irrigation development since 1950. Irrigated fields extend to the active streambank through much of the reach.

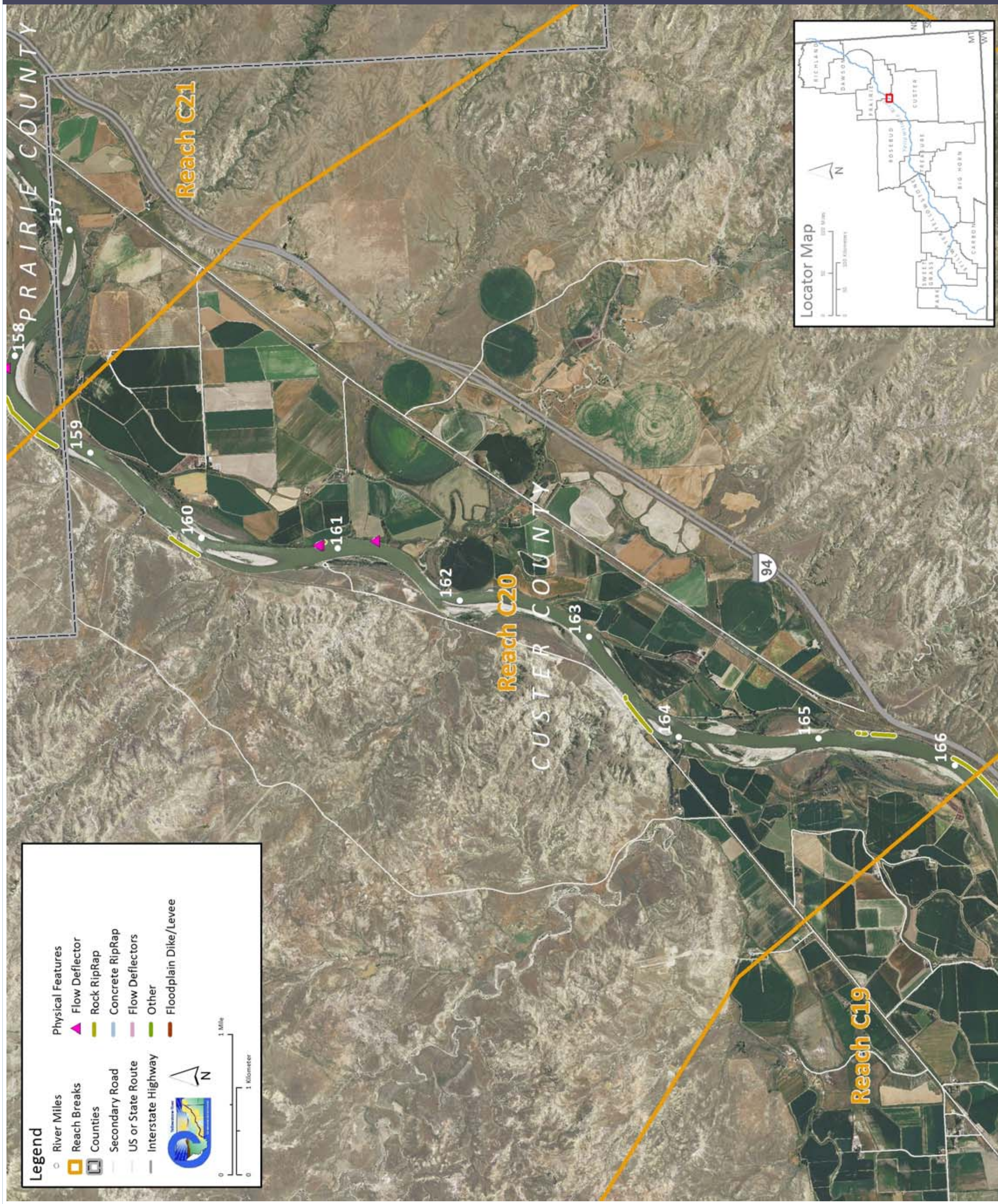
There are 84 acres of Russian olive in the reach. The Russian olive is concentrated on tributaries and in riparian areas colonizing old river swales, mostly in the upstream portion of the reach.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The magnitude of 100-year flood has dropped by 19 percent due to flow alterations associated with human development. The 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 5,080 cfs to 3,150 cfs with human development, a reduction of 38 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,750 cfs under unregulated conditions to 3,510 cfs under regulated conditions, a reduction of 48 percent.

CEA-Related observations in Reach C20 include:
•Irrigated land encroachment in reach stabilized by bedrock
•Bank armor on abandoned rail line on northern bluff

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C20 include:
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	127.9	17.8

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		63,800	79,600	89,500	110,000	119,000	139,000	5,080	6,750
Regulated		48,600	63,400	72,300	89,700	96,400	111,000	3,150	3,510
% Change		-23.82%	-20.35%	-19.22%	-18.45%	-18.99%	-20.14%	-37.99%	-48.00%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	62,400	23,400	6,460
	Regulated	48,100	14,000	4,670
	% Change	**-23%**	**-40%**	**-28%**
Summer	Unregulated	44,400	14,100	6,750
	Regulated	33,400	8,570	3,510
	% Change	**-25%**	**-39%**	**-48%**
Fall	Unregulated	9,410	5,750	2,320
	Regulated	10,800	7,120	3,740
	% Change	**15%**	**24%**	**61%**
Winter	Unregulated	12,500	5,180	2,080
	Regulated	13,200	6,260	3,340
	% Change	**6%**	**21%**	**61%**
Annual	Unregulated	46,900	8,340	2,870
	Regulated	35,100	7,660	3,730
	% Change	**-25%**	**-8%**	**30%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	7/9/96 - 8/1/96	B/W		6309000	35000
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6309000	3500
2005	NAIP	07/08/2005	color	1-meter pixels	6309000	18800
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	4,410	5.5%	6,059	7.6%	1,650
	Flow Deflectors	0	0.0%	76	0.1%	76
	Between Flow Deflectors	0	0.0%	55	0.1%	55
	Feature Type Totals	**4,410**	**5.5%**	**6,191**	**7.8%**	**1,781**
	Reach Totals	**4,410**	**5.5%**	**6,191**	**7.8%**	**1,781**

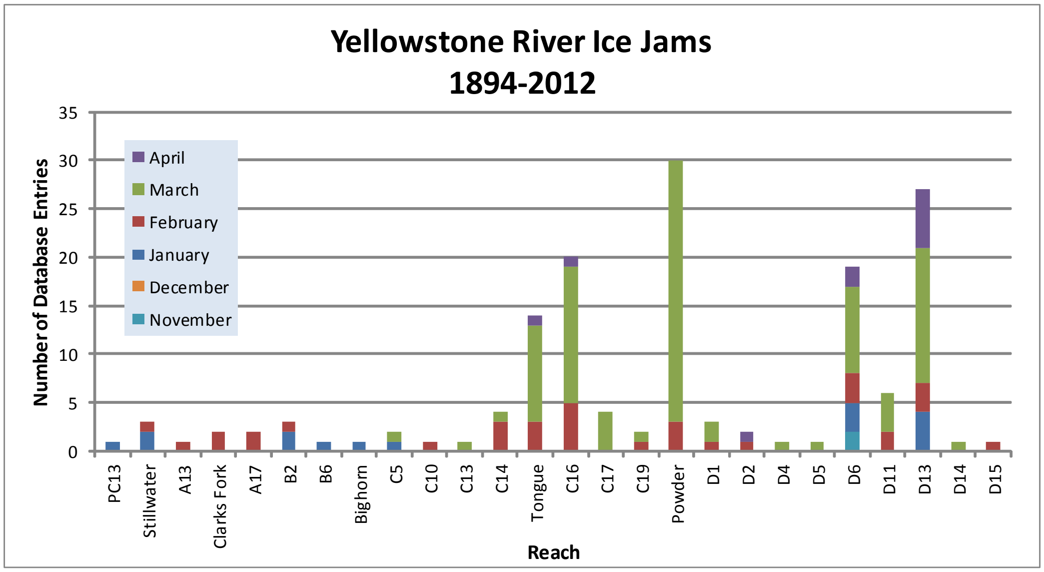
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	0	0	0	0	0	3,414	0	0
Totals	**0**	**0**	**0**	**0**	**0**	**3,414**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	40,718	3,954	1.10	1950 to 1976:	6.78%
1976	40,017	6,863	1.17	1976 to 1995:	-4.31%
1995	39,899	4,828	1.12	1995 to 2001:	0.00%
2001	39,899	4,828	1.12	1950 to 2001:	2.18%
Change 1950 - 2001	**-819**	**874**	**0.02**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	48	12.6%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	336		818	
Total Floodplain Area (Ac)	385		914	
Total Isolated (Ac)	**48**	**12.6%**	**95**	**55.2%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	1	0	0	**1**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
83	166	1,071	0	0%	59	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Irrigated	2	0.1%
	Totals	**2**	**0.1%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
28.4	0.0	3.1	1.9	1.2

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	43	120	168	158	0.6%	1.7%	2.4%	2.2%
	Totals	**43**	**120**	**168**	**158**	**0.6%**	**1.7%**	**2.4%**	**2.2%**
Agricultural Land									
	Non-Irrigated	3,391	3,066	3,057	2,955	47.6%	43.1%	42.9%	41.5%
	Irrigated	2,725	2,924	2,947	3,041	38.3%	41.1%	41.4%	42.7%
	Totals	**6,116**	**5,990**	**6,004**	**5,996**	**85.9%**	**84.1%**	**84.3%**	**84.2%**
Channel									
	Channel	849	812	762	781	11.9%	11.4%	10.7%	11.0%
	Totals	**849**	**812**	**762**	**781**	**11.9%**	**11.4%**	**10.7%**	**11.0%**
ExUrban									
	ExUrban Other	0	0	2	2	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**2**	**2**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	45	34	60	60	0.6%	0.5%	0.8%	0.8%
	Interstate	0	95	95	95	0.0%	1.3%	1.3%	1.3%
	Railroad	68	70	29	29	1.0%	1.0%	0.4%	0.4%
	Totals	**113**	**200**	**184**	**184**	**1.6%**	**2.8%**	**2.6%**	**2.6%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	327	0.0%	0.0%	0.0%	5.5%	0.0%	0.0%	5.5%	5.5%
	Flood	2,725	2,924	2,946	2,714	44.6%	48.8%	49.1%	45.3%	4.3%	0.3%	-3.8%	0.7%
	Totals	**2,725**	**2,924**	**2,947**	**3,041**	**44.6%**	**48.8%**	**49.1%**	**50.7%**	**4.3%**	**0.3%**	**1.6%**	**6.2%**

Non-Irrigated

Multi-Use	3,327	2,864	2,848	2,775	54.4%	47.8%	47.4%	46.3%	-6.6%	-0.4%	-1.2%	-8.1%
Hay/Pasture	64	203	209	180	1.1%	3.4%	3.5%	3.0%	2.3%	0.1%	-0.5%	1.9%
Totals	**3,391**	**3,066**	**3,057**	**2,955**	**55.4%**	**51.2%**	**50.9%**	**49.3%**	**-4.3%**	**-0.3%**	**-1.6%**	**-6.2%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.3	1.6	0.8	0.2	1.6	1.3	1.4	1.1	1.4
Max	28.8	91.1	99.8	26.7	20.4	30.3	18.3	37.4	54.6
Average	6.9	12.9	11.4	6.3	7.3	5.8	6.1	11.1	18.0
Sum	137.6	206.4	193.5	43.9	58.6	69.1	42.4	77.8	89.8

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	22.8
Channel to Riparian (acres)	73.1
Riparian Encroachment (acres)	**50.3**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	110.0
1950s Floodplain Mapped as 2011 Channel (Ac)	17.9
Total Recruitment (1950s to 2011)(Ac)	**127.9**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	5.7	49.2	1.6	0.0	**56.5**
Acres/Valley Mile	0.8	6.7	0.2	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	83.74	1.99%	6.56	0.00	11.92	2.85

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	337.4	189.3	24.8%
Rip Rap Margin	142.9	96.4	12.7%
Terrace Pool	62.7	61.4	8.1%
Secondary Channel		13.6	1.8%
Secondary Channel (Seasonal)	41.5	52.9	6.9%
Channel Crossover	156.1	122.0	16.0%
Point Bar		52.7	6.9%
Side Bar		58.1	7.6%
Mid-channel Bar		44.1	5.8%
Island	31.7	31.7	4.2%
Dry Channel		39.9	5.2%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Custer	**Upstream River Mile**	158.7
Classification	CM: Confined meandering	**Downstream River Mile**	149.2
General Location	To Powder River confluence	**Length**	9.50 mi (15.29 km)
General Comments	To Powder River; confined		

Narrative Summary

Reach C21 is 9.5 miles long and extends from River Mile (RM) 158.7 downstream to the mouth of the Powder River at RM 149.2. It is a Confined Meandering (CM) reach type, as the river flows down a sinuous course that is highly confined by Fort Union Formation sandstones and younger erosion–resistant terraces.

Reach C21 has just over 4,000 feet of rock riprap and 71 feet of mapped flow deflectors, which collectively armor 4.1 percent of the total stream bank. About one half of the armor is protecting road embankments, and the other half is protecting the railroad.

Bear Rapids forms two distinct shoals as bedrock shelves in the river between RM 153 and RM 154 near the mouth of Camp Creek.

Between 1950 and 2001 there was about 53 net acres of riparian encroachment into the channel, and the bankfull channel area decreased by ~58 acres, indicating a diminishing river size over the last half-century. This trend is common below the mouth of the Bighorn River, where flow alterations have reduced peak flows and cause the active river channel to shrink. Consumptive water uses, primarily associated with irrigation, have contributed to the reduced flows.

Land use is dominated by agriculture with 164 acres of the ~7,000 acre mapping footprint occupied by transportation-related land uses. There is one ~0.6 acre series of corrals near the mouth of Mack Creek at RM 157.2R that are within 200 feet of the river. There are also several acres of corrals within 300 feet of the river on the left bank at RM 154.9L. At RM 153.3R there is another much larger series of corrals that are within 500 feet of Camp Creek.

There are 49 acres of Russian olive in the reach, which appears to dominate riparian areas.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped by 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 5,080 cfs to 3,140 cfs with human development, a reduction of 38 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,730 cfs under unregulated conditions to 3,510 cfs under regulated conditions, a reduction of 48 percent.

CEA-Related observations in Reach C21 include:
•Natural channel stability provided by bedrock
•Minimal bank armoring

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C21 include:
•Russian olive removal
•Nutrient management at corrals at RM 157.2R and RM 153.2R, and 154.9L

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	118.4	25.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		63,900	79,700	89,700	111,000	119,000	139,000	5,080	6,750
Regulated		48,600	63,500	72,500	90,000	96,800	111,000	3,140	3,510
% Change		-23.94%	-20.33%	-19.18%	-18.92%	-18.66%	-20.14%	-38.19%	-48.00%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Season		5%	50%	95%
Spring	Unregulated	62,400	23,400	6,470
	Regulated	48,100	14,000	4,670
	% Change	**-23%**	**-40%**	**-28%**
Summer	Unregulated	44,400	14,100	6,750
	Regulated	33,400	8,580	3,510
	% Change	**-25%**	**-39%**	**-48%**
Fall	Unregulated	9,420	5,760	2,320
	Regulated	10,800	7,130	3,740
	% Change	**15%**	**24%**	**61%**
Winter	Unregulated	12,600	5,180	2,080
	Regulated	13,300	6,260	3,340
	% Change	**6%**	**21%**	**61%**
Annual	Unregulated	46,900	8,350	2,870
	Regulated	35,100	7,670	3,730
	% Change	**-25%**	**-8%**	**30%**

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	???	B/W	1:14,800	6309000	
1976	USCOE	9/29/1976 - 10/9/76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	9-Jul-96	B/W		6309000	35000
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6309000	3500
2005	NAIP	08/04/2005	color	1-meter pixels	6309000	5550
2005	NAIP	07/08/2005	color	1-meter pixels	6309000	18800
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	8/11/2009	Color	1-meter pixels	6309000	12900
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	4,066	4.1%	4,025	4.0%	-41
	Flow Deflectors	0	0.0%	71	0.1%	71
	Feature Type Totals	**4,066**	**4.1%**	**4,096**	**4.1%**	**30**
Other In Channel						
	Bedrock Outcrop	2,854	2.9%	2,854	2.9%	0
	Feature Type Totals	**2,854**	**2.9%**	**2,854**	**2.9%**	**0**
	Reach Totals	**6,919**	**6.9%**	**6,949**	**6.9%**	**30**

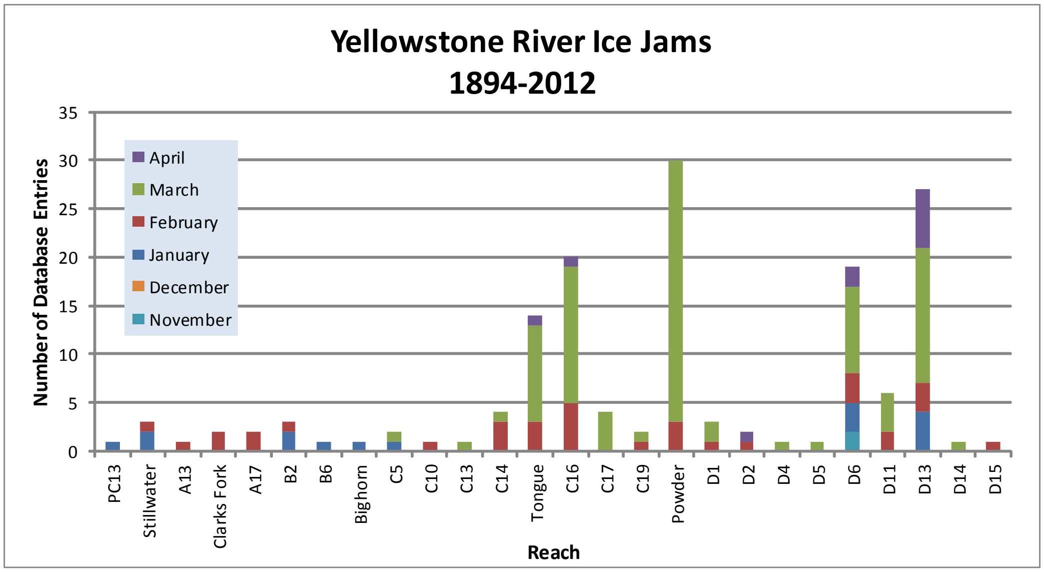
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	0	0	0	2,378	0	2,676	0	0
Totals	**0**	**0**	**0**	**2,378**	**0**	**2,676**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	50,040	3,028	1.06	1950 to 1976:	14.55%
1976	50,142	10,774	1.21	1976 to 1995:	2.48%
1995	50,158	12,286	1.24	1995 to 2001:	-9.91%
2001	50,035	6,080	1.12	1950 to 2001:	5.75%
Change 1950 - 2001	**-5**	**3,052**	**0.06**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	13	2.6%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	469		1090	
Total Floodplain Area (Ac)	481		1185	
Total Isolated (Ac)	**13**	**2.6%**	**95**	**35.3%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	0	**0**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
85	169	1,395	2	0%	56	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Railroad	2	0.2%
	Totals	**2**	**0.2%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
9.3	0.0	0.0	0.0	4.9

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	35	95	100	100	0.5%	1.2%	1.3%	1.3%
	Totals	**35**	**95**	**100**	**100**	**0.5%**	**1.2%**	**1.3%**	**1.3%**
Agricultural Land									
	Non-Irrigated	4,830	4,332	4,818	4,611	61.9%	55.6%	61.8%	59.1%
	Irrigated	1,799	2,165	1,737	1,916	23.1%	27.8%	22.3%	24.6%
	Totals	**6,629**	**6,497**	**6,556**	**6,527**	**85.0%**	**83.3%**	**84.1%**	**83.7%**
Channel									
	Channel	1,032	1,026	967	996	13.2%	13.2%	12.4%	12.8%
	Totals	**1,032**	**1,026**	**967**	**996**	**13.2%**	**13.2%**	**12.4%**	**12.8%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	11	11	0.0%	0.0%	0.1%	0.1%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**11**	**11**	**0.0%**	**0.0%**	**0.1%**	**0.1%**
Transportation									
	Public Road	28	32	57	57	0.4%	0.4%	0.7%	0.7%
	Interstate	0	76	76	76	0.0%	1.0%	1.0%	1.0%
	Railroad	72	72	31	31	0.9%	0.9%	0.4%	0.4%
	Totals	**100**	**180**	**164**	**164**	**1.3%**	**2.3%**	**2.1%**	**2.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	488	0	0	0.0%	7.5%	0.0%	0.0%	7.5%	-7.5%	0.0%	0.0%
	Flood	1,799	1,676	1,737	1,916	27.1%	25.8%	26.5%	29.4%	-1.3%	0.7%	2.9%	2.2%
	Totals	**1,799**	**2,165**	**1,737**	**1,916**	**27.1%**	**33.3%**	**26.5%**	**29.4%**	**6.2%**	**-6.8%**	**2.9%**	**2.2%**

Non-Irrigated													
	Multi-Use	4,746	4,193	4,077	4,066	71.6%	64.5%	62.2%	62.3%	-7.0%	-2.3%	0.1%	-9.3%
	Hay/Pasture	84	139	741	545	1.3%	2.1%	11.3%	8.4%	0.9%	9.2%	-2.9%	7.1%
	Totals	**4,830**	**4,332**	**4,818**	**4,611**	**72.9%**	**66.7%**	**73.5%**	**70.6%**	**-6.2%**	**6.8%**	**-2.9%**	**-2.2%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.6	0.7	0.1	1.5	1.5	1.9	2.4	2.4	1.5
Max	15.6	34.3	64.9	12.6	10.8	16.0	29.0	12.2	28.5
Average	4.9	7.7	6.4	5.2	4.6	5.9	8.2	4.9	8.9
Sum	113.4	246.8	199.7	57.3	36.8	47.5	73.4	19.5	98.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	33.4
Channel to Riparian (acres)	86.8
Riparian Encroachment (acres)	**53.3**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	119.4
1950s Floodplain Mapped as 2011 Channel (Ac)	9.7
Total Recruitment (1950s to 2011)(Ac)	**129.2**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	7.7	61.4	10.5	0.0	**79.6**
Acres/Valley Mile	0.9	7.2	1.2	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	48.62	0.84%	2.39	0.00	8.70	0.30

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	73.5	87.7	9.1%
Rip Rap Bottom	78.2	53.3	5.5%
Rip Rap Margin	62.6	7.6	0.8%
Terrace Pool	384.5	227.9	23.6%
Secondary Channel	27.3	28.8	3.0%
Secondary Channel (Seasonal)	47.7	91.3	9.4%
Channel Crossover	226.7	187.1	19.3%
Point Bar		55.1	5.7%
Side Bar		30.3	3.1%
Mid-channel Bar		95.0	9.8%
Island	53.7	53.7	5.6%
Dry Channel		44.7	4.6%
Confluence Area	4.0	4.5	0.5%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Prairie	**Upstream River Mile**	149.2
Classification	CM: Confined meandering	**Downstream River Mile**	137
General Location	To Terry Bridge	**Length**	12.20 mi (19.63 km)
General Comments	To Terry Bridge; confined		

Narrative Summary

Reach D1 is located in Prairie County, and extends from just below the mouth of the Powder River to Terry. The reach is a 12.2 mile long Confined Meandering (CM) reach type, indicating that the river flows along a meandering course that is confined by older geologic units. Sandstones of the Fort Union Formation and younger erosion-resistant terraces confine the channel through the reach. Because of the geologic confinement, channel migration rates are low and the riparian corridor is notably thin or absent. There is one Fishing Access Site at the upper end of the reach at the Powder River confluence (Powder River Depot).

There are less than 1000 feet of bank armor in the reach; including about 550 feet of rock riprap and 140 feet of flow deflectors. The flow deflectors were all built between 2001 and 2011. During that timeframe there was a loss of 650 feet or rock riprap where it was protecting an old railroad bridge at RM 144.5. The bridge was built in 1907 for the railroad and now serves County Road 42.

Wolf Rapids is located on the apex of a large meander at RM 146. These rapids are formed from an exposed bedrock shelf that extends across the entire river.

Reach D1 has lost almost a mile of side channel length since 1950, but none of this loss has been associated with intentional blockages. There has been 126 acres of riparian recruitment into abandoned 1950s channels.

Land use is predominantly agricultural, and there has been 310 acres of land developed under pivot irrigation. There are two animal handling facilities just north of Terry that are adjacent to old swales. One dump site was mapped on the right bank of the river at RM 137.5R, about ¾ miles upstream from the Terry Bridge.

About 51 percent of the historic 5-year floodplain has become isolated, primarily due to flow alterations. The abandoned Milwaukee rail line embankment has been breached by river erosion in several locations on the south side of the river.

A total of four ice jams have been reported in the reach. One of these events was in February (1996), and three occurred in March (1993, 2009, and 2011). No damages were reported.

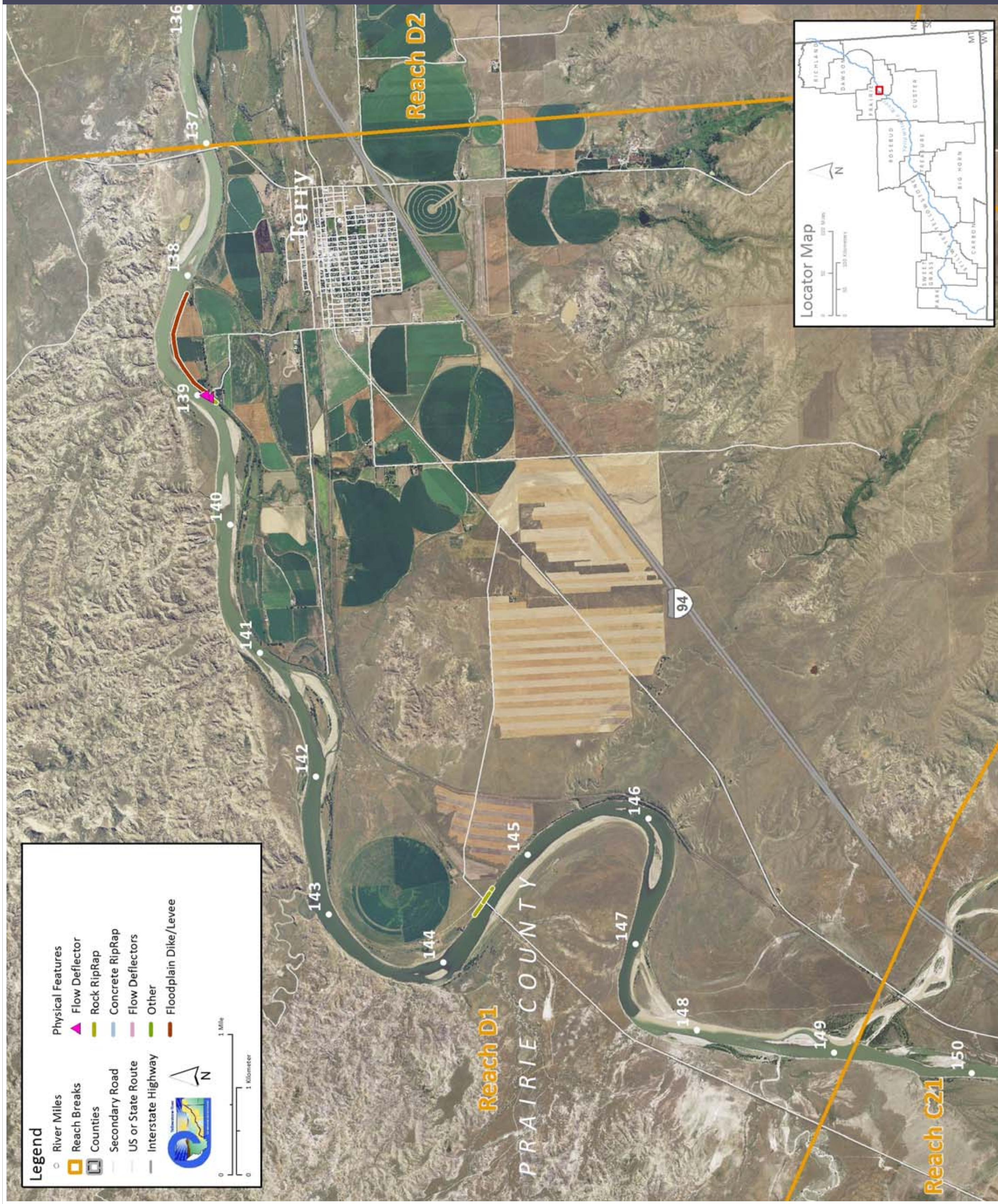
There are about 20 acres of mapped Russian olive in the reach.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 22 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,850 cfs to 2,810 cfs with human development, a reduction of 42 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,940 cfs under unregulated conditions to 3,270 cfs under regulated conditions, a reduction of 53 percent.

CEA-Related observations in Reach D1 include:
•Breaching of abandoned Milwaukee Railroad line

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D1 include:
•Dump site Practice at RM 137.5R
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	106.2	34.8

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		68,200	87,300	99,900	128,000	140,000	169,000	4,850	6,940
Regulated		53,000	71,700	83,600	109,000	119,000	142,000	2,810	3,280
% Change		-22.29%	-17.87%	-16.32%	-14.84%	-15.00%	-15.98%	-42.06%	-52.74%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Season		5%	50%	95%
Spring	Unregulated	66,400	24,800	6,810
	Regulated	51,200	14,800	4,970
	% Change	**-23%**	**-40%**	**-27%**
Summer	Unregulated	46,600	14,700	6,940
	Regulated	34,800	8,850	3,280
	% Change	**-25%**	**-40%**	**-53%**
Fall	Unregulated	9,690	5,920	2,090
	Regulated	11,100	7,380	3,610
	% Change	**15%**	**25%**	**73%**
Winter	Unregulated	14,100	5,300	2,100
	Regulated	14,700	6,450	3,410
	% Change	**4%**	**22%**	**62%**
Annual	Unregulated	49,200	8,790	2,830
	Regulated	36,700	7,940	3,670
	% Change	**-25%**	**-10%**	**30%**

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1976	USCOE	9-Oct-76	B/W	1:24,000	6329500	9580
1995	USGS DOQQ	1995??	B/W		6329500	
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6329500	4000
2005	NAIP	08/05/2005	color	1-meter pixels	6329500	4170
2005	NAIP	08/04/2005	color	1-meter pixels	6329500	4350
2007	Woolpert	10/15/2007 - 11/2/0007	Color		6329500	
2009	NAIP	8/11/2009	Color	1-meter pixels	6329500	13000
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/25/2011	Color	1-meter pixels	6329500	41100
2011	NAIP	7/16/2011	Color	1-meter pixels	6329500	60100
2013	NAIP	07/24/2013	color	1-meter pixels	6329500	
2013	NAIP	07/19/2013	color	1-meter pixels	6329500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	1,196	0.9%	545	0.4%	-651
	Flow Deflectors	0	0.0%	113	0.1%	113
	Between Flow Deflectors	0	0.0%	130	0.1%	130
	Feature Type Totals	**1,196**	**0.9%**	**787**	**0.6%**	**-409**
Other In Channel						
	Bedrock Outcrop	1,429	1.1%	1,429	1.1%	0
	Feature Type Totals	**1,429**	**1.1%**	**1,429**	**1.1%**	**0**
Floodplain Control						
	Floodplain Dike/Levee	4,290	3.4%	4,290	3.4%	0
	Feature Type Totals	**4,290**	**3.4%**	**4,290**	**3.4%**	**0**
	Reach Totals	**6,914**	**5.4%**	**6,506**	**5.1%**	**-409**

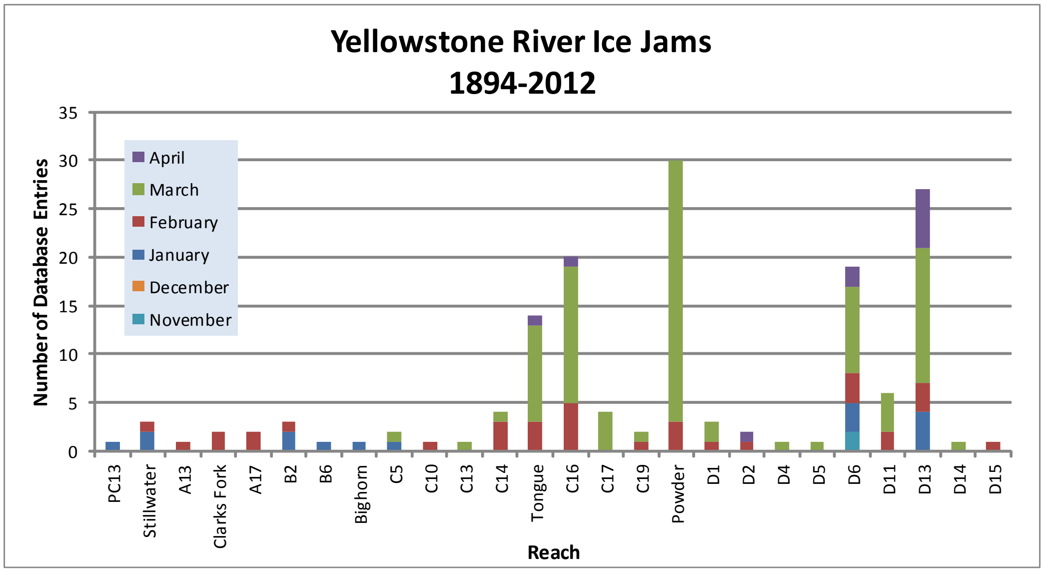
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	0	0	0	1,197	0	0	0	0
Totals	**0**	**0**	**0**	**1,197**	**0**	**0**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
3/26/1993	Break-up	137	?
2/9/1996	Break-up	137	?
3/3/2009	Break-up		None known
3/14/2011	Break-up		

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	65,951	16,560	1.25	1950 to 1976:	2.31%
1976	63,797	17,862	1.28	1976 to 1995:	-6.65%
1995	63,973	12,462	1.19	1995 to 2001:	0.01%
2001	63,919	12,462	1.19	1950 to 2001:	-4.49%
Change 1950 - 2001	**-2,032**	**-4,098**	**-0.06**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	15	3.3%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	440		1321	
Total Floodplain Area (Ac)	455		1417	
Total Isolated (Ac)	**15**	**3.3%**	**95**	**51.3%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	0	**0**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
120	241	1,889	12	1%	0	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	12	0.6%
	Totals	**12**	**0.6%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
21.7	0.0	2.0	0.1	5.1

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	7	31	64	57	0.1%	0.4%	0.8%	0.7%
	Totals	**7**	**31**	**64**	**57**	**0.1%**	**0.4%**	**0.8%**	**0.7%**
Agricultural Land									
	Non-Irrigated	5,846	5,654	5,499	5,383	73.8%	71.4%	69.4%	67.9%
	Irrigated	682	866	1,048	1,157	8.6%	10.9%	13.2%	14.6%
	Totals	**6,529**	**6,519**	**6,547**	**6,540**	**82.4%**	**82.3%**	**82.6%**	**82.5%**
Channel									
	Channel	1,283	1,257	1,221	1,251	16.2%	15.9%	15.4%	15.8%
	Totals	**1,283**	**1,257**	**1,221**	**1,251**	**16.2%**	**15.9%**	**15.4%**	**15.8%**
ExUrban									
	ExUrban Other	0	16	16	16	0.0%	0.2%	0.2%	0.2%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**16**	**16**	**16**	**0.0%**	**0.2%**	**0.2%**	**0.2%**
Transportation									
	Public Road	31	25	42	27	0.4%	0.3%	0.5%	0.3%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	72	74	32	32	0.9%	0.9%	0.4%	0.4%
	Totals	**104**	**99**	**74**	**59**	**1.3%**	**1.2%**	**0.9%**	**0.7%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	202	310	0.0%	0.0%	3.1%	4.7%	0.0%	3.1%	1.7%	4.7%
	Flood	682	866	846	846	10.5%	13.3%	12.9%	12.9%	2.8%	-0.4%	0.0%	2.5%
	Totals	**682**	**866**	**1,048**	**1,157**	**10.5%**	**13.3%**	**16.0%**	**17.7%**	**2.8%**	**2.7%**	**1.7%**	**7.2%**

Non-Irrigated													
	Multi-Use	5,405	5,129	5,205	5,212	82.8%	78.7%	79.5%	79.7%	-4.1%	0.8%	0.2%	-3.1%
	Hay/Pasture	441	524	294	171	6.8%	8.0%	4.5%	2.6%	1.3%	-3.5%	-1.9%	-4.1%
	Totals	**5,846**	**5,654**	**5,499**	**5,383**	**89.5%**	**86.7%**	**84.0%**	**82.3%**	**-2.8%**	**-2.7%**	**-1.7%**	**-7.2%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	1.6	0.9	0.2	3.3	1.7	0.7	2.9	4.8	3.9
Max	17.6	33.6	21.6	32.4	19.7	23.1	13.0	23.3	17.3
Average	5.0	5.1	5.0	14.7	6.4	5.5	6.6	13.4	11.1
Sum	69.7	97.7	44.9	88.1	44.5	43.8	39.8	80.5	66.3

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	27.1
Channel to Riparian (acres)	34.2
Riparian Encroachment (acres)	**7.2**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	126.0
1950s Floodplain Mapped as 2011 Channel (Ac)	7.6
Total Recruitment (1950s to 2011)(Ac)	**133.6**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	27.0	18.0	0.0	0.0	**45.0**
Acres/Valley Mile	3.0	2.0	0.0	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	19.88	1.36%	40.51	0.07	6.50	0.37

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	**Bankfull**	**Low Flow**	**% of Low Flow**
Scour Pool	90.2	81.8	6.4%
Rip Rap Bottom	78.2	48.0	3.8%
Bluff Pool	235.1	183.6	14.4%
Terrace Pool	350.6	212.5	16.7%
Secondary Channel	63.2	40.6	3.2%
Secondary Channel (Seasonal)	29.4	49.1	3.9%
Channel Crossover	373.3	299.2	23.5%
Point Bar		105.0	8.3%
Side Bar		117.9	9.3%
Mid-channel Bar		66.6	5.2%
Island	50.1	23.1	1.8%
Dry Channel		41.5	3.3%
Confluence Area		2.7	0.2%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.

There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

Yellowstone River Reach Narratives Reach D2

County	Prairie	**Upstream River Mile**	137
Classification	CM: Confined meandering	**Downstream River Mile**	126.5
General Location	To Fallon, I-90 Bridge	**Length**	10.50 mi (16.90 km)
General Comments	To Fallon, I-90 Bridge; confined		

Narrative Summary

Reach D2 is located in Prairie County, and extends from Terry to Fallon and the I-90 Bridge. The reach is a 10.5 mile long Confined Meandering (CM) reach type, indicating that the river flows along a meandering course that is confined by older geologic units. Sandstones of the Fort Union Formation and younger erosion-resistant terraces confine the channel through the reach. Because of the geologic confinement, channel migration rates are low and the riparian corridor is notably thin or absent. The Channel Migration Zone (CMZ) is extremely narrow because there has been essentially no bank migration in this reach since 1950.

There are just over 1,000 feet of bank armor in the reach; all of which is rock riprap that is protecting the Fallon Bridge.

Land use is predominantly agricultural with more acreage irrigated under pivot than under flood; as of 2011 there were 712 acres in flood and 1,070 acres in pivot in the reach. All of the pivots are on the north side of the river, and several of them extend to the river bank.

One dump site was mapped on the right bank at RM 135.1. There is also an animal handling facility on lower O'Fallon Creek near RM 130.

About 57 percent of the historic 5-year floodplain has become isolated, primarily due to flow alterations. There has been almost 50 acres of riparian encroachment in the reach, likely due to reduced 2-year flows.

Two ice jams have been reported in the reach. In early April of 1943, the breakup of ice jams at Fallon resulted in a 13 foot rise in the river stage at Intake. According to records, many of the farmers "remained in their homes, taking refuge in the attics and second floors of their homes, and some in the haylofts of their barns". More recently in February 1996, lowland flooding resulted from another ice jam breakup.

There are about 20 acres of mapped Russian olive in the reach.

Bluff pools and terrace pools make up 57 percent of the low flow fish habitat mapped in the reach, indicating that this reach may provide important areas for fish species that prefer this habitat type.

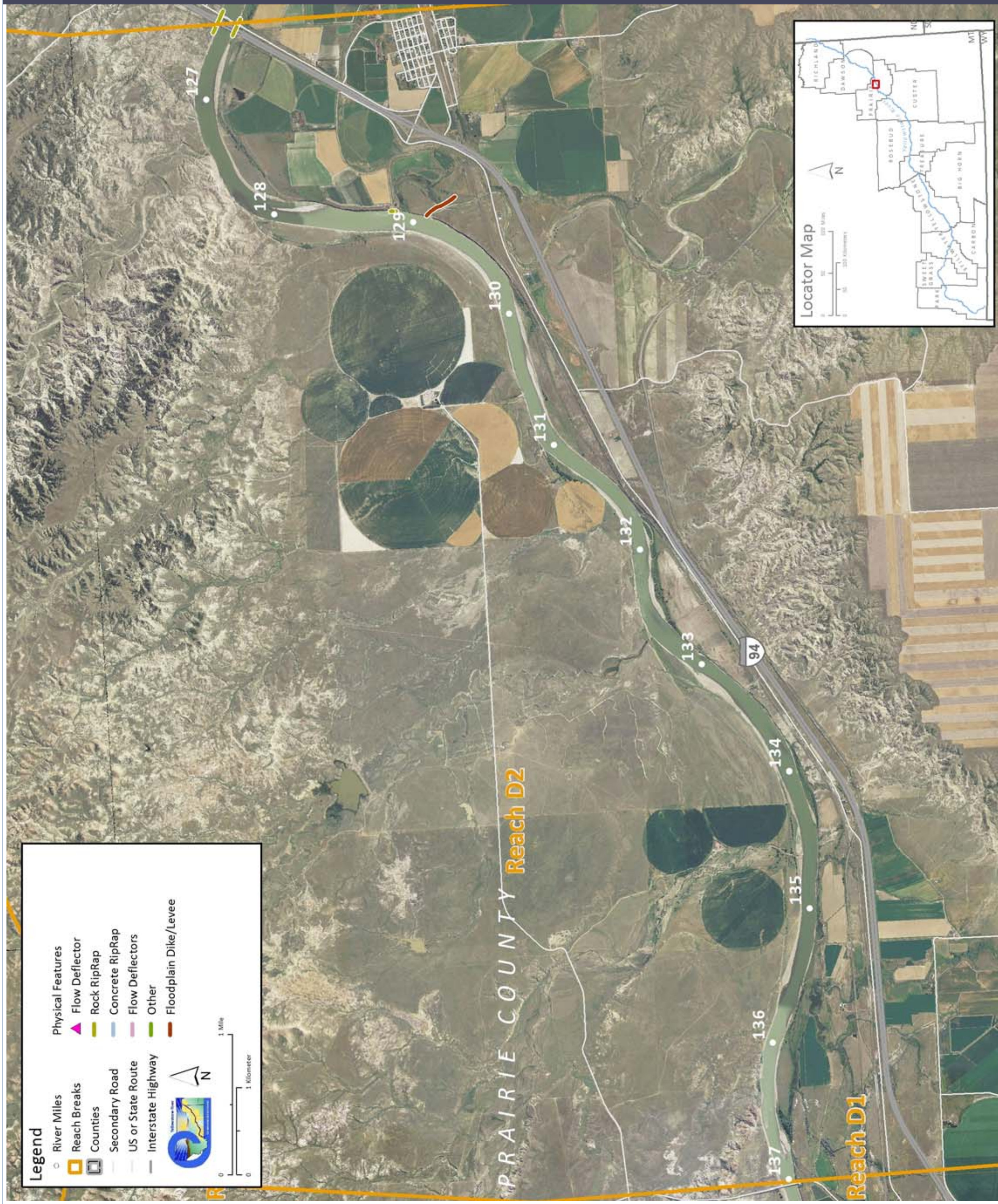
O'Fallon Creek enters the Yellowstone River at RM 129. The lowermost 3,100 feet of this creek has been diked off, and the channel now bypasses that remnant and flows directly into the Yellowstone. This abandoned channel supports some emergent wetland and could potentially provide excellent restoration opportunities for wetlands and slackwater areas connected to the Yellowstone River in this highly confined reach.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 22 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,850 cfs to 2,810 cfs with human development, a reduction of 43 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,940 cfs under unregulated conditions to 3,270 cfs under regulated conditions, a reduction of 53 percent.

CEA-Related observations in Reach D2 include:
•Breaching of abandoned Milwaukee Railroad line
•Diking of lower O'Fallon Creek and isolation of ~3,000 feet of historic tributary channel

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D2 include:
•Dump site YRRP at RM 137.5R
•Nutrient management at animal handling facility on lower O'Fallon Creek RM 130
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	95.7	47.0

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		68,300	87,500	100,000	128,000	141,000	170,000	4,850	6,940
Regulated		53,100	72,000	84,000	109,000	120,000	143,000	2,790	3,270
% Change		-22.25%	-17.71%	-16.00%	-14.84%	-14.89%	-15.88%	-42.47%	-52.88%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Season		5%	50%	95%
Spring	Unregulated	66,500	24,900	6,820
	Regulated	51,300	14,800	4,980
	% Change	**-23%**	**-41%**	**-27%**
Summer	Unregulated	46,700	14,700	6,940
	Regulated	34,900	8,860	3,270
	% Change	**-25%**	**-40%**	**-53%**
Fall	Unregulated	9,700	5,920	2,090
	Regulated	11,100	7,390	3,610
	% Change	**14%**	**25%**	**73%**
Winter	Unregulated	14,100	5,300	2,100
	Regulated	14,700	6,450	3,410
	% Change	**4%**	**22%**	**62%**
Annual	Unregulated	49,300	8,810	2,830
	Regulated	36,800	7,950	3,670
	% Change	**-25%**	**-10%**	**30%**

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1976	USCOE	9-Oct-76	B/W	1:24,000	6329500	9580
1995	USGS DOQQ	8/26/96 - 8/27/96	B/W		6329500	5700
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6329500	4000
2005	NAIP	08/05/2005	color	1-meter pixels	6329500	4170
2005	NAIP	08/04/2005	color	1-meter pixels	6329500	4350
2005	NAIP	07/28/2005	color	1-meter pixels	6329500	5110
2007	Woolpert	10/15/2007 - 11/2/0007	Color		6329500	
2009	NAIP	8/11/2009	Color	1-meter pixels	6329500	13000
2009	NAIP	8/10/2009	Color	1-meter pixels	6329500	13700
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/25/2011	Color	1-meter pixels	6329500	41100
2011	NAIP	7/20/2011	Color	1-meter pixels	6329500	48800
2013	NAIP	07/24/2013	color	1-meter pixels	6329500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	889	0.8%	1,055	0.9%	166
	Feature Type Totals	**889**	**0.8%**	**1,055**	**0.9%**	**166**
Floodplain Control						
	Floodplain Dike/Levee	1,279	1.1%	1,279	1.1%	0
	Feature Type Totals	**1,279**	**1.1%**	**1,279**	**1.1%**	**0**
	Reach Totals	**2,168**	**1.9%**	**2,334**	**2.1%**	**166**

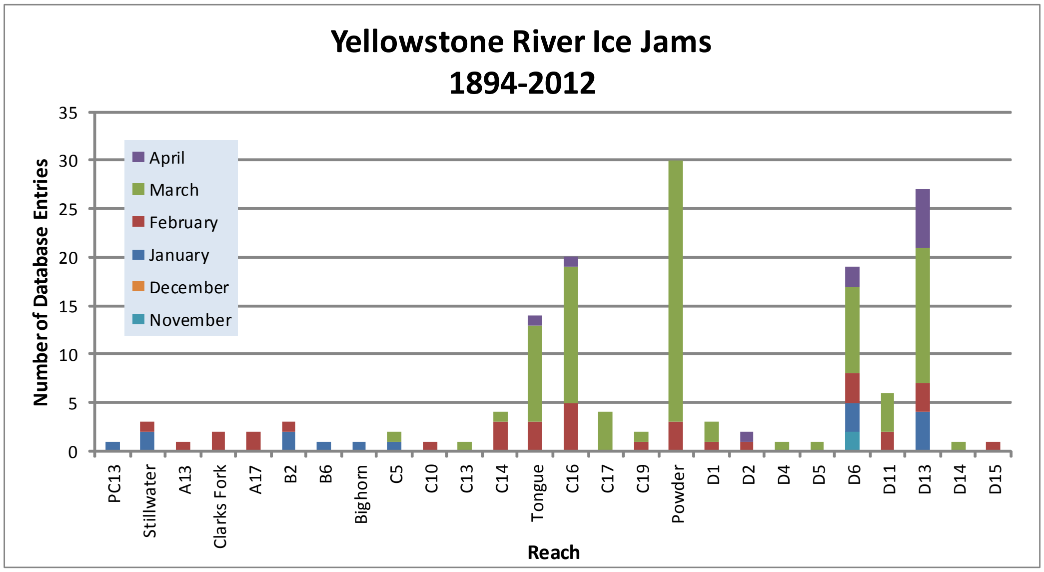
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	0	0	0	0	672	0	0	0
Totals	**0**	**0**	**0**	**0**	**672**	**0**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
4/1/1943	Break-up	127	Severe flooding affecting farmers
2/1/1996	Break-up	127	Lowland flooding

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	56,281		1.00	1950 to 1976:	4.55%
1976	55,880	2,540	1.05	1976 to 1995:	-4.35%
1995	55,920		1.00	1995 to 2001:	0.00%
2001	55,920		1.00	1950 to 2001:	0.00%
Change 1950 - 2001	**-361**		**0.00**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	40	7.2%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	515		1071	
Total Floodplain Area (Ac)	554		1171	
Total Isolated (Ac)	**40**	**7.2%**	**101**	**56.7%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	0	**0**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
46	92	1,232	6	0%	0	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	2	0.1%
RipRap			
	Interstate	4	0.3%
	Totals	**6**	**0.5%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
2.4	0.0	0.3	0.0	2.3

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	10	64	67	61	0.1%	0.8%	0.8%	0.7%
	Totals	**10**	**64**	**67**	**61**	**0.1%**	**0.8%**	**0.8%**	**0.7%**
Agricultural Land									
	Non-Irrigated	6,415	5,982	5,027	5,001	78.2%	72.9%	61.3%	60.9%
	Irrigated	631	779	1,761	1,782	7.7%	9.5%	21.5%	21.7%
	Totals	**7,046**	**6,761**	**6,789**	**6,783**	**85.9%**	**82.4%**	**82.7%**	**82.7%**
Channel									
	Channel	1,008	1,000	999	1,011	12.3%	12.2%	12.2%	12.3%
	Totals	**1,008**	**1,000**	**999**	**1,011**	**12.3%**	**12.2%**	**12.2%**	**12.3%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	34	0	0	0.0%	0.4%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	3	3	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**34**	**3**	**3**	**0.0%**	**0.4%**	**0.0%**	**0.0%**
Transportation									
	Public Road	61	57	54	54	0.7%	0.7%	0.7%	0.7%
	Interstate	0	210	219	219	0.0%	2.6%	2.7%	2.7%
	Railroad	81	81	76	76	1.0%	1.0%	0.9%	0.9%
	Totals	**142**	**348**	**348**	**348**	**1.7%**	**4.2%**	**4.2%**	**4.2%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	907	1,070	0.0%	0.0%	13.4%	15.8%	0.0%	13.4%	2.4%	15.8%
	Flood	631	779	854	712	8.9%	11.5%	12.6%	10.5%	2.6%	1.1%	-2.1%	1.5%
	Totals	**631**	**779**	**1,761**	**1,782**	**8.9%**	**11.5%**	**25.9%**	**26.3%**	**2.6%**	**14.4%**	**0.3%**	**17.3%**

Non-Irrigated													
	Multi-Use	5,363	5,278	4,383	4,815	76.1%	78.1%	64.6%	71.0%	1.9%	-13.5%	6.4%	-5.1%
	Hay/Pasture	1,052	704	644	186	14.9%	10.4%	9.5%	2.7%	-4.5%	-0.9%	-6.7%	-12.2%
	Totals	**6,415**	**5,982**	**5,027**	**5,001**	**91.1%**	**88.5%**	**74.1%**	**73.7%**	**-2.6%**	**-14.4%**	**-0.3%**	**-17.3%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.5	1.1	1.2	0.2	1.1	0.9	49.5		1.7
Max	72.7	69.9	94.0	12.8	18.3	13.0	49.5		78.1
Average	11.4	12.9	13.0	4.5	9.9	6.8	49.5		22.9
Sum	182.2	321.8	234.5	31.7	49.7	27.3	49.5		91.7

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	5.2
Channel to Riparian (acres)	53.5
Riparian Encroachment (acres)	**48.3**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	72.2
1950s Floodplain Mapped as 2011 Channel (Ac)	1.6
Total Recruitment (1950s to 2011)(Ac)	**73.8**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	11.0	22.9	4.5	0.0	**38.4**
Acres/Valley Mile	1.1	2.3	0.5	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	10.79	0.96%	30.21	0.29	1.36	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Bluff Pool	231.1	176.5	17.7%
Terrace Pool	549.1	397.3	39.8%
Secondary Channel		10.3	1.0%
Secondary Channel (Seasonal)	19.1	2.8	0.3%
Channel Crossover	179.9	165.8	16.6%
Point Bar		68.5	6.9%
Side Bar		71.5	7.2%
Mid-channel Bar		9.2	0.9%
Island	19.6	19.6	2.0%
Dry Channel		77.5	7.8%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.

There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

County	Prairie	**Upstream River Mile**	126.5
Classification	PCS: Partially confined straight	**Downstream River Mile**	118.1
General Location	Downstream of Fallon Bridge	**Length**	8.40 mi (13.52 km)
General Comments	Hugs right bank wall; into Dawson County		

Narrative Summary

Reach D3 straddles the Prairie/Dawson County line, extending from the Fallon Bridge to about two miles into Dawson County. The reach is 8.4 miles long and has been classified as a Partially Confined Straight (PCS) reach type, indicating minimal meandering and some influence of the valley wall on river form and process. Sandstones of the Fort Union Formation typically form the south bank, and younger erosion-resistant terraces confine the channel to the north. Because of the geologic confinement, channel migration rates are low and the riparian corridor is notably thin or absent. The Channel Migration Zone (CMZ) is extremely narrow because there has been only minor bank migration in this reach since 1950. All of the migration measured in the reach was at RM 123, where the river abruptly hits the south valley wall and apparently backwaters as it has developed a series of islands that drive local bank movement. From 1950 to 2011, the right bank migrated almost 900 feet at this single location. These islands provide areas for riparian colonization and habitat for bird species such as least terns.

Approximately 1,500 feet of bank armor have been mapped in the reach; about 2/3 of that armor protects the Interstate Bridge, with the remainder (600 feet) protecting irrigated land. Two pipelines cross the river about 1,000 feet downstream from the Interstate Bridge. One is an 8-inch petroleum product line that has been abandoned and purged, and the other is a product line that was directionally drilled in 1999. About 4,000 feet downstream from the Fallon Bridge, three large bridge piers from an old trestle remain in the middle of the river.

The Glendive Pump Station #1 is located about two miles downstream of the Fallon Bridge at RM 124.5L and is part of the Glendive Unit of the Buffalo Rapids Project. Construction of the unit began November 12, 1937, with ground breaking for excavation of the main canal. The following April 1938, excavation began on the lateral system. The first operation of the pumping station occurred on September 26, 1939, before the Unit was completed; diverted water was allowed to flow about ten miles down the main canal. Ice damage in 2012 required in extensive repairs to the pumping station. The unit serves 16,500 acres of irrigated land.

Land use in Reach D3 is predominantly agricultural, with about 600 acres of pivot irrigation development since 1950. All of the pivots are on the north side of the river, and several of them extend to the river bank and into the CMZ. In total, 57 acres of land under pivot irrigation are within the CMZ, making them especially prone to the threat of bank erosion. Although there has been extensive pivot development, most irrigated land had remained in flood irrigation in 2011 (1,500 acres).

Dump sites were mapped on the banks or in adjacent riparian areas at RM 125.6R, RM 124.2L, and RM 122L.

The most recently available map of the proposed Keystone Pipeline route shows that the line would cross the Yellowstone River at the lower end of Reach D3, at approximately RM 118.2 (www.keystone.steamingmules.com). The river is at Milepost 198 on the proposed pipeline route.

About 108 acres or 49 percent of the historic 5-year floodplain has become isolated in Reach D3, primarily due to flow alterations.

There are 11 acres of mapped Russian olive in the reach.

Bluff pools and terrace pools make up 22 percent of the low flow fish habitat mapped in the reach, indicating that this reach may provide important areas for fish species that prefer this habitat type.

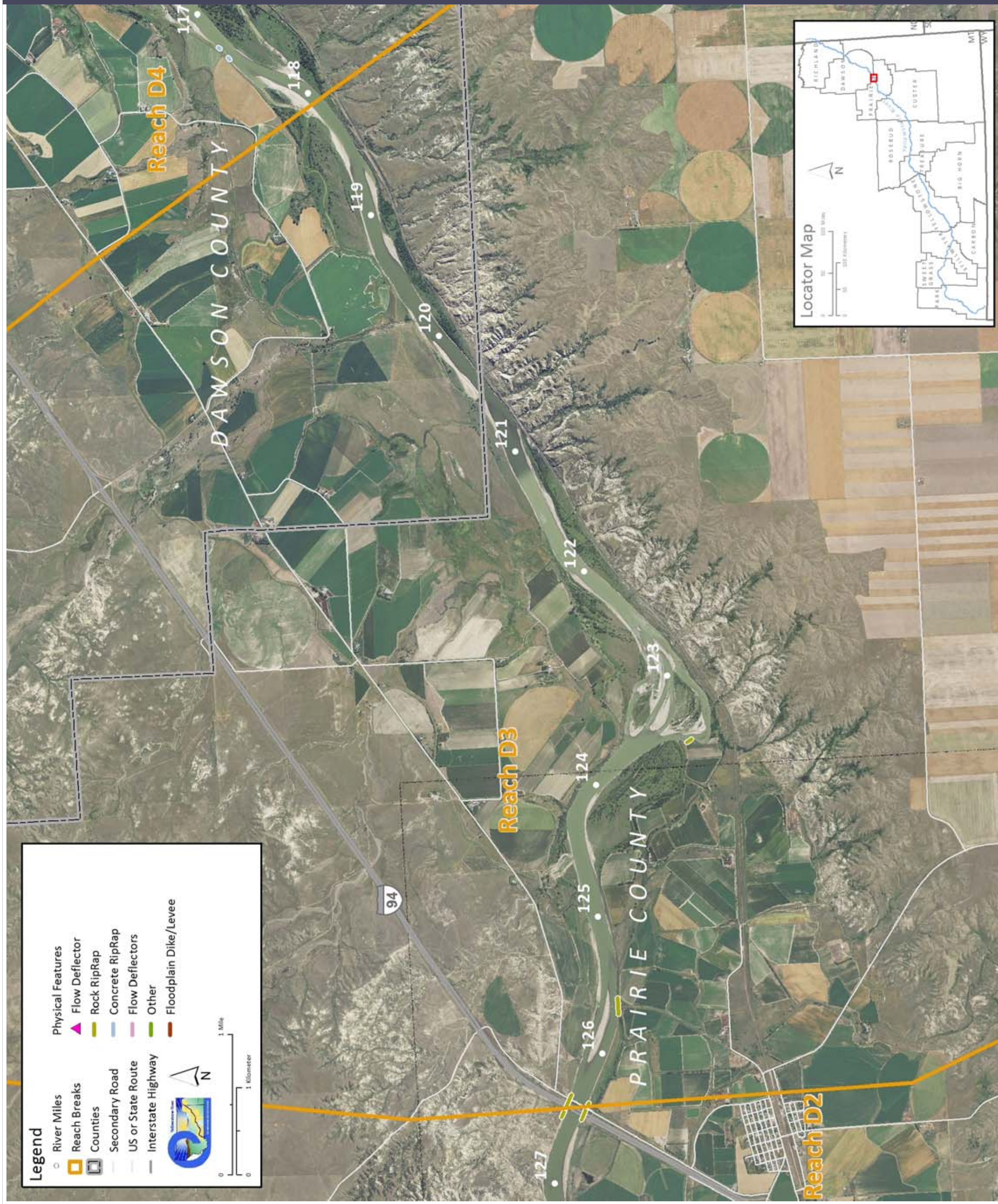
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The magnitude of the 100-year flood is now 20,000 cfs or 14 percent lower than it was pre-development. The 2-year flood, which strongly influences overall channel form, has dropped by 22 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,820 cfs to 2,750 cfs with human development, a reduction of 43 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,970 cfs under unregulated conditions to 3,240 cfs under regulated conditions, a reduction of 55 percent.

Seasonal low flows have increased by 62 percent in the winter and 75 percent in the fall.

CEA-Related observations in Reach D3 include:
•Isolation of historic 5-year floodplain area due to flow alterations

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D3 include:
•Solid waste (dump site) removal at RM 125.6R, RM 124.2L, and RM 122L
•Pipeline crossing practices at RM 126.2
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	87.3	57.5

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		68,900	88,500	102,000	131,000	143,000	174,000	4,820	6,970
Regulated		53,700	73,000	85,400	112,000	123,000	147,000	2,750	3,240
% Change		-22.06%	-17.51%	-16.27%	-14.50%	-13.99%	-15.52%	-42.95%	-53.52%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	67,000	25,000	6,870
	Regulated	51,700	14,900	5,010
	% Change	**-23%**	**-40%**	**-27%**
Summer	Unregulated	46,900	14,800	6,970
	Regulated	35,000	8,900	3,240
	% Change	**-25%**	**-40%**	**-54%**
Fall	Unregulated	9,740	5,940	2,060
	Regulated	11,200	7,420	3,600
	% Change	**15%**	**25%**	**75%**
Winter	Unregulated	14,300	5,320	2,110
	Regulated	14,900	6,480	3,420
	% Change	**4%**	**22%**	**62%**
Annual	Unregulated	49,600	8,860	2,820
	Regulated	37,000	7,990	3,660
	% Change	**-25%**	**-10%**	**30%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1976	USCOE	9-Oct-76	B/W	1:24,000	6329500	9580
1995	USGS DOQQ	7/9/96 - 8/26/96	B/W		6329500	35000
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6329500	4000
2005	NAIP	08/05/2005	color	1-meter pixels	6329500	4170
2007	Woolpert	10/15/2007 - 11/2/0007	Color		6329500	
2009	NAIP	8/10/2009	Color	1-meter pixels	6329500	13700
2009	NAIP	8/1/2009	Color	1-meter pixels	6329500	12600
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/20/2011	Color	1-meter pixels	6329500	48800
2013	NAIP	07/27/2013	color	1-meter pixels	6329500	
2013	NAIP	07/24/2013	color	1-meter pixels	6329500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	1,283	1.5%	1,493	1.7%	210
	Feature Type Totals	**1,283**	**1.5%**	**1,493**	**1.7%**	**210**
	Reach Totals	**1,283**	**1.5%**	**1,493**	**1.7%**	**210**

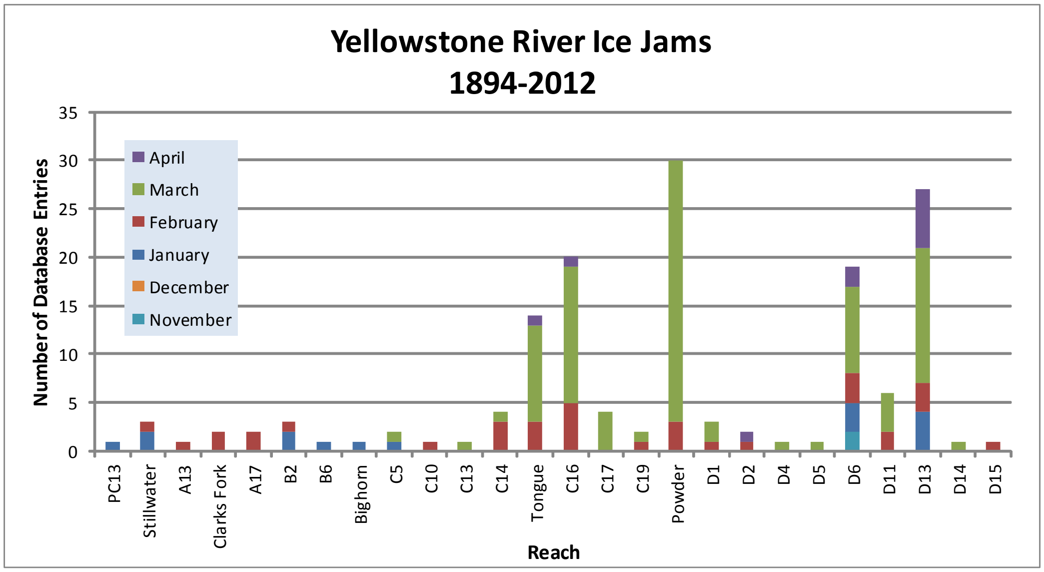
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	597	0	0	0	902	0	0	0
Totals	**597**	**0**	**0**	**0**	**902**	**0**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	45,233	13,093	1.29
1976	43,598	16,577	1.38
1995	43,654	17,992	1.41
2001	44,080	19,230	1.44
Change 1950 - 2001	**-1,153**	**6,136**	**0.15**

	% Change in Braiding
1950 to 1976:	7.04%
1976 to 1995:	2.31%
1995 to 2001:	1.71%
1950 to 2001:	11.38%

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	101	12.7%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	695		988	
Total Floodplain Area (Ac)	796		1096	
Total Isolated (Ac)	**101**	**12.7%**	**108**	**48.7%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	3	**3**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
188	376	1,717	18	1%	137	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Irrigated	9	0.5%
	Interstate	8	0.4%
	Totals	**18**	**1.0%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
59.9	0.0	57.4	0.0	4.4

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	12	11	12	12	0.2%	0.2%	0.2%	0.2%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	9	64	63	57	0.1%	0.9%	0.9%	0.8%
	Totals	**21**	**75**	**75**	**69**	**0.3%**	**1.1%**	**1.1%**	**1.0%**
Agricultural Land									
	Non-Irrigated	4,387	3,890	4,076	3,596	63.5%	56.3%	59.0%	52.1%
	Irrigated	1,421	1,835	1,621	2,102	20.6%	26.6%	23.5%	30.4%
	Totals	**5,808**	**5,725**	**5,697**	**5,698**	**84.1%**	**82.9%**	**82.5%**	**82.5%**
Channel									
	Channel	1,009	1,038	1,054	1,058	14.6%	15.0%	15.3%	15.3%
	Totals	**1,009**	**1,038**	**1,054**	**1,058**	**14.6%**	**15.0%**	**15.3%**	**15.3%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	24	24	24	24	0.3%	0.3%	0.3%	0.3%
	Interstate	0	0	13	13	0.0%	0.0%	0.2%	0.2%
	Railroad	41	41	41	41	0.6%	0.6%	0.6%	0.6%
	Totals	**65**	**65**	**78**	**78**	**0.9%**	**0.9%**	**1.1%**	**1.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	43	598	0.0%	0.0%	0.8%	10.5%	0.0%	0.8%	9.7%	10.5%
	Flood	1,421	1,835	1,578	1,504	24.5%	32.1%	27.7%	26.4%	7.6%	-4.4%	-1.3%	1.9%
	Totals	**1,421**	**1,835**	**1,621**	**2,102**	**24.5%**	**32.1%**	**28.4%**	**36.9%**	**7.6%**	**-3.6%**	**8.4%**	**12.4%**

Non-Irrigated													
	Multi-Use	4,133	3,809	4,004	3,493	71.2%	66.5%	70.3%	61.3%	-4.6%	3.8%	-9.0%	-9.9%
	Hay/Pasture	254	81	72	104	4.4%	1.4%	1.3%	1.8%	-3.0%	-0.1%	0.6%	-2.6%
	Totals	**4,387**	**3,890**	**4,076**	**3,596**	**75.5%**	**67.9%**	**71.6%**	**63.1%**	**-7.6%**	**3.6%**	**-8.4%**	**-12.4%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.8	0.2	1.3	0.3	4.1	1.1	1.2	4.2	0.0
Max	145.5	131.6	99.4	40.2	38.1	156.2	68.0	53.8	52.8
Average	15.7	27.1	20.9	19.8	14.2	28.0	21.9	21.0	18.0
Sum	345.1	542.2	418.0	98.9	142.5	196.1	175.3	105.2	108.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	42.3
Channel to Riparian (acres)	56.1
Riparian Encroachment (acres)	**13.8**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	84.6
1950s Floodplain Mapped as 2011 Channel (Ac)	39.3
Total Recruitment (1950s to 2011)(Ac)	**123.9**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	12.1	80.1	7.1	0.0	**99.3**
Acres/Valley Mile	1.5	10.2	0.9	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	10.70	0.86%	24.13	0.01	0.88	0.12

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	290.7	173.4	16.5%
Bluff Pool	85.2	47.0	4.5%
Terrace Pool	223.7	190.1	18.0%
Secondary Channel	56.2	69.2	6.6%
Secondary Channel (Seasonal)	53.3	42.6	4.0%
Channel Crossover	183.5	154.4	14.6%
Point Bar		23.9	2.3%
Side Bar		51.5	4.9%
Mid-channel Bar		31.5	3.0%
Island	179.0	179.0	17.0%
Dry Channel		91.4	8.7%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

County	Dawson	**Upstream River Mile**	118.1
Classification	PCM/I: Partially confined meandering/islands	**Downstream River Mile**	107.1
General Location	Hoyt	**Length**	11.00 mi (17.70 km)

General Comments

Narrative Summary

Reach D4 is located in western Dawson County. The reach is 11 miles long and has a meandering planform with forested islands that formed where meanders have cut off.

Approximately 1,500 feet of bank armor have been mapped in the reach, including 920 feet of rock riprap and 590 feet of concrete riprap. This armor collectively covers about 1.3 percent of the bankline.

Prior to 1950, a side channel on the south floodplain at RM 110.8R was blocked by a small dike. This channel remnant is about a mile and a half long and currently has blockages at its middle and lower end.

Similar to many reaches in the Lower Yellowstone Valley, the river channel in Reach D4 has gotten smaller since 1950. The channel contracted by about 115 acres in this reach since 1950, and about 84 acres of riparian vegetation has encroached into old channel areas. This pattern has been consistent in the lower river, and relates primarily to a reduction in flows due to human development. Although there has been net encroachment of riparian vegetation, most of this cover is either shrub or open timber. The extent of closed timber dropped from 371 acres in 1950 to 191 acres in 2001.

Land use is predominantly agricultural, with about 180 acres of pivot irrigation development since 1950. About 20 acres of land in pivot irrigation has encroached into the Channel Migration Zone (CMZ), making it especially susceptible to damage by river erosion. Although there has been extensive pivot development, most irrigated land had remained in flood irrigation in 2011 (2,300 acres). Approximately 125 acres of flood irrigated land is within the CMZ.

One solid waste dump site was mapped on the right bank at RM 117.8L. Animal handling facilities (corral complexes) were mapped within a few thousand feet of the river at RM 112.2R, RM 114L, and RM 116L.

About 195 acres or 46 percent of the historic 5-year floodplain has become isolated, primarily due to flow alterations.

There are 16 acres of mapped Russian olive in the reach. Most of the Russian olive is in tributary drainages that flow into the Yellowstone River from the north.

Due to a reduction in the extent of closed timber with time, the extent of riparian forest considered at low risk of cowbird parasitism in Reach D4 has been reduced since 1950. At that time, there were 36.5 acres per mile of forest considered less prone to cowbirds, but by 2001 that had dropped to 14.7 acres per mile of such forest.

One ice jam was recorded in Reach D4. On March 4, 1994, a breakup jam forced local evacuations due to flooding.

Bluff pools and terrace pools make up 22 percent of the low flow fish habitat mapped in the reach, indicating that this reach may provide important areas for fish species that prefer this habitat type.

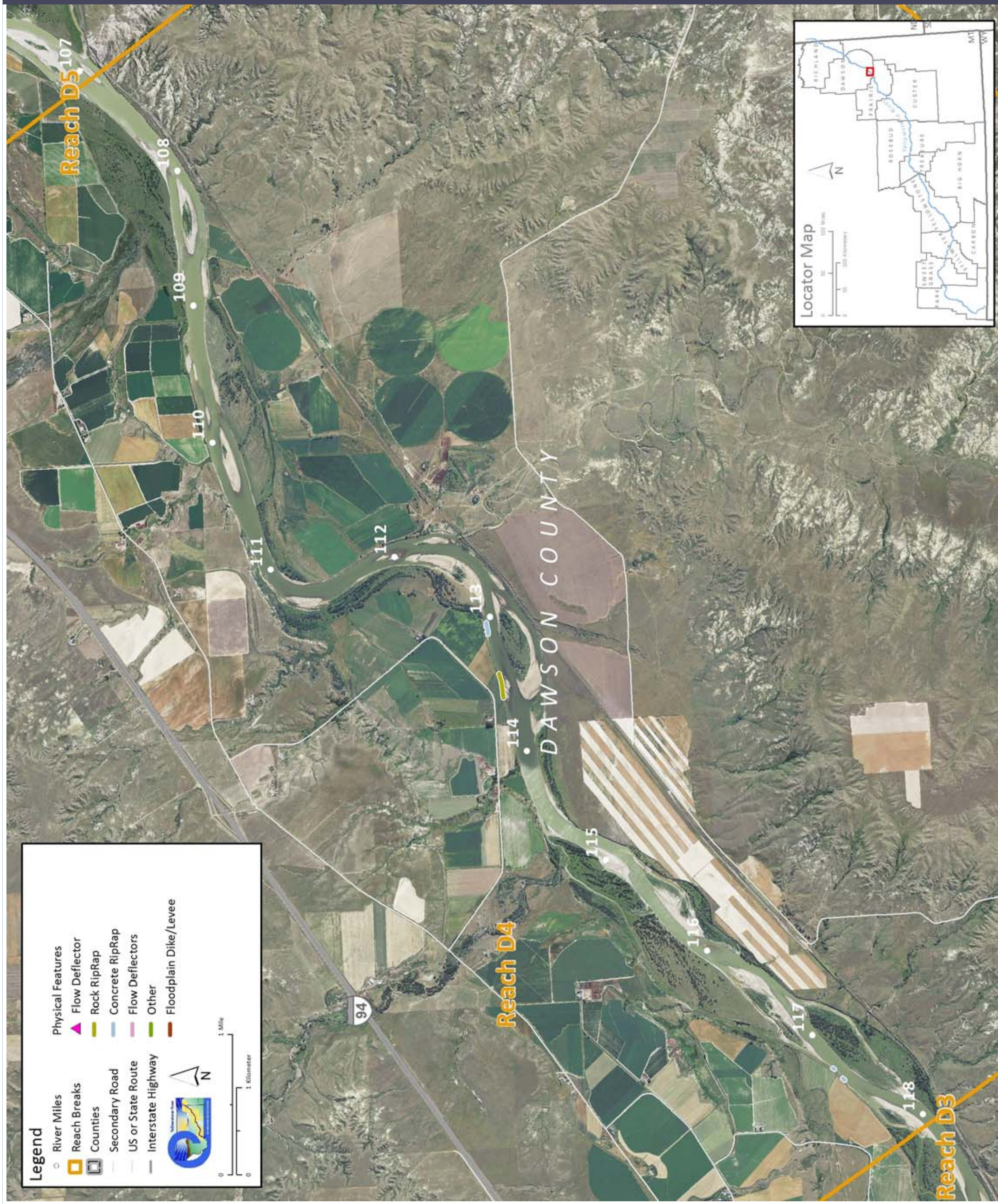
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The magnitude of the 100-year flood is now 121,000 cfs, or 14 percent lower than it was pre-development. The 2-year flood, which strongly influences overall channel form, has dropped by 22 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,800 cfs to 2,730 cfs with human development, a reduction of 43 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,980 cfs under unregulated conditions to 3,220 cfs under regulated conditions, a reduction of 54 percent.

Seasonal low flows have increased by 63 percent in the winter and 76 percent in the fall.

CEA-Related observations in Reach D4 include:
•Increased risk of cowbird parasitism with loss of closed timber

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D4 include:
•Side channel reactivation at RM 110.3R
•Solid waste (dump site) removal at RM 117.8L
•Russian olive removal
•Nutrient management at corral complexes at RM 112.2R, RM 114L, and RM 116L

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	76.3	65.9

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		69,100	88,900	102,000	132,000	145,000	175,000	4,800	6,980
Regulated		53,900	73,500	86,100	113,000	124,000	149,000	2,730	3,220
% Change		-22.00%	-17.32%	-15.59%	-14.39%	-14.48%	-14.86%	-43.13%	-53.87%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Season		5%	50%	95%
Spring	Unregulated	67,300	25,100	6,890
	Regulated	51,900	15,000	5,030
	% Change	**-23%**	**-40%**	**-27%**
Summer	Unregulated	47,100	14,900	6,980
	Regulated	35,100	8,910	3,220
	% Change	**-25%**	**-40%**	**-54%**
Fall	Unregulated	9,750	5,950	2,040
	Regulated	11,200	7,430	3,590
	% Change	**15%**	**25%**	**76%**
Winter	Unregulated	14,400	5,320	2,110
	Regulated	15,000	6,490	3,430
	% Change	**4%**	**22%**	**63%**
Annual	Unregulated	49,800	8,890	2,820
	Regulated	37,100	8,000	3,650
	% Change	**-26%**	**-10%**	**29%**

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1976	USCOE	9-Oct-76	B/W	1:24,000	6329500	9580
1995	USGS DOQQ	6/12/96 - 8/8/96 - 7/9/96	B/W		6329500	
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6329500	4000
2004	Merrick	20-May-04	Color	1:15,840	6329500	5070
2005	NAIP	08/05/2005	color	1-meter pixels	6329500	4170
2005	NAIP	07/31/2005	color	1-meter pixels	6329500	5280
2009	NAIP	8/1/2009	Color	1-meter pixels	6329500	12600
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/20/2011	Color	1-meter pixels	6329500	48800
2013	NAIP	07/24/2013	color	1-meter pixels	6329500	
2013	NAIP	07/27/2013	color	1-meter pixels	6329500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	0	0.0%	921	0.8%	921
	Concrete RipRap	0	0.0%	587	0.5%	587
	Feature Type Totals		**0.0%**	**1,509**	**1.3%**	
Other In Channel						
	Bedrock Outcrop	1,961	1.7%	1,961	1.7%	0
	Feature Type Totals	**1,961**	**1.7%**	**1,961**	**1.7%**	**0**
	Reach Totals	**1,961**	**1.7%**	**3,469**	**3.0%**	**1,509**

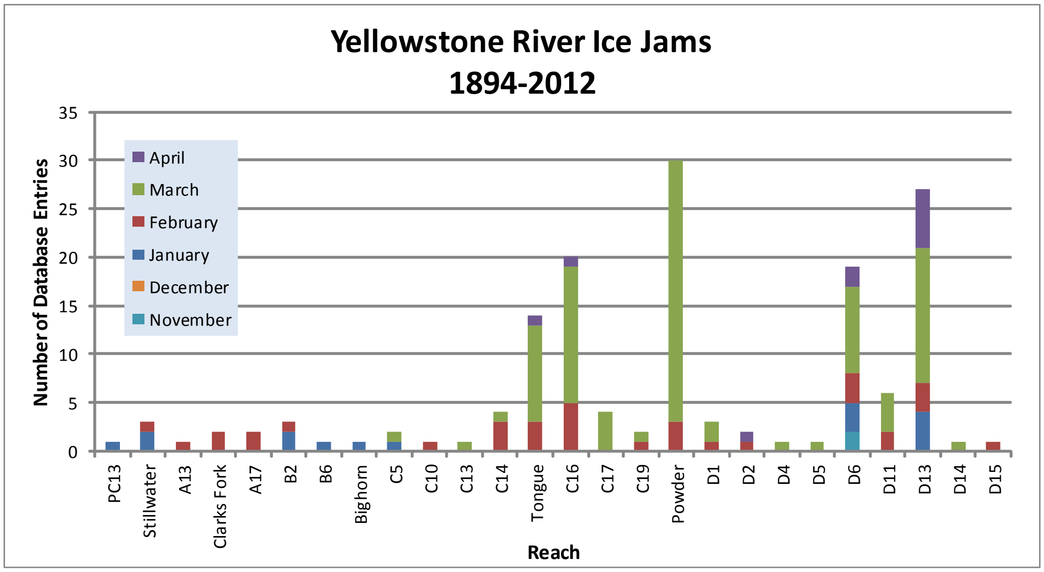
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	0	1,978	1,978	1,978	1,978	1,978
	Totals	**0**	**1,978**	**1,978**	**1,978**	**1,978**	**1,978**
Other Off Channel							
	Floodplain Dike/Levee	0	481	481	481	481	481
	Totals	**0**	**481**	**481**	**481**	**481**	**481**
Transportation Encroachment							
	Railroad	18,032	18,032	18,032	18,032	18,032	18,032
	Totals	**18,032**	**18,032**	**18,032**	**18,032**	**18,032**	**18,032**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
3/4/1994	Break-up	115	Evacuations

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	59,835	38,509	1.64
1976	58,168	34,978	1.60
1995	58,151	29,871	1.51
2001	57,997	23,767	1.41
Change 1950 - 2001	**-1,838**	**-14,742**	**-0.23**

	% Change in Braiding
1950 to 1976:	-2.57%
1976 to 1995:	-5.47%
1995 to 2001:	-6.86%
1950 to 2001:	-14.22%

Length of Side Channels Blocked

Pre-1950s (ft)	8,549
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	98	7.7%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1171		1463	
Total Floodplain Area (Ac)	1269		1658	
Total Isolated (Ac)	**98**	**7.7%**	**195**	**46.0%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	0	**0**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
194	388	2,581	38	1%	194	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Irrigated	18	0.6%
Dike/Levee			
	Railroad	38	1.3%
	Totals	**55**	**2.0%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
125.3	0.0	19.8	0.0	7.4

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	75	70	140	143	0.8%	0.7%	1.5%	1.5%
	Totals	**75**	**70**	**140**	**143**	**0.8%**	**0.7%**	**1.5%**	**1.5%**
Agricultural Land									
	Non-Irrigated	6,022	5,263	5,482	5,350	63.0%	55.1%	57.4%	56.0%
	Irrigated	1,601	2,384	2,446	2,545	16.8%	24.9%	25.6%	26.6%
	Totals	**7,623**	**7,646**	**7,929**	**7,895**	**79.8%**	**80.0%**	**83.0%**	**82.6%**
Channel									
	Channel	1,770	1,752	1,400	1,431	18.5%	18.3%	14.7%	15.0%
	Totals	**1,770**	**1,752**	**1,400**	**1,431**	**18.5%**	**18.3%**	**14.7%**	**15.0%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	35	35	35	35	0.4%	0.4%	0.4%	0.4%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	52	52	52	52	0.5%	0.5%	0.5%	0.5%
	Totals	**88**	**87**	**87**	**87**	**0.9%**	**0.9%**	**0.9%**	**0.9%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	44	0.0%	0.0%	0.0%	0.6%	0.0%	0.0%	0.6%	0.6%
	Pivot	0	120	94	180	0.0%	1.6%	1.2%	2.3%	1.6%	-0.4%	1.1%	2.3%
	Flood	1,601	2,264	2,352	2,321	21.0%	29.6%	29.7%	29.4%	8.6%	0.1%	-0.3%	8.4%
	Totals	**1,601**	**2,384**	**2,446**	**2,545**	**21.0%**	**31.2%**	**30.9%**	**32.2%**	**10.2%**	**-0.3%**	**1.4%**	**11.2%**

Non-Irrigated													
	Multi-Use	3,481	4,225	4,539	4,430	45.7%	55.3%	57.2%	56.1%	9.6%	2.0%	-1.1%	10.4%
	Hay/Pasture	2,541	1,038	943	920	33.3%	13.6%	11.9%	11.7%	-19.8%	-1.7%	-0.2%	-21.7%
	Totals	**6,022**	**5,263**	**5,482**	**5,350**	**79.0%**	**68.8%**	**69.1%**	**67.8%**	**-10.2%**	**0.3%**	**-1.4%**	**-11.2%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.3	0.2	0.2	1.8	2.2	2.9	2.7	7.0	2.9
Max	100.4	130.6	147.3	57.4	108.1	39.9	54.8	53.5	86.9
Average	16.4	17.2	22.4	28.6	25.5	17.4	18.9	24.2	20.2
Sum	556.0	688.0	671.9	371.5	331.2	191.2	151.5	145.4	222.0

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	108.5
Channel to Riparian (acres)	193.1
Riparian Encroachment (acres)	**84.5**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	258.6
1950s Floodplain Mapped as 2011 Channel (Ac)	34.4
Total Recruitment (1950s to 2011)(Ac)	**293.0**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	8.0	103.2	24.3	0.0	**135.5**
Acres/Valley Mile	0.8	10.1	2.4	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	16.30	1.65%	80.00	0.00	3.42	1.01

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	256.5	189.9	13.6%
Bluff Pool	153.4	132.1	9.4%
Terrace Pool	208.3	183.9	13.1%
Secondary Channel	82.3	60.1	4.3%
Secondary Channel (Seasonal)	114.7	125.4	9.0%
Channel Crossover	401.3	246.6	17.6%
Point Bar		39.1	2.8%
Side Bar		83.7	6.0%
Mid-channel Bar		60.8	4.3%
Island	165.8	166.9	11.9%
Dry Channel		111.6	8.0%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

County	Dawson	**Upstream River Mile**	107.1
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	94.6
General Location	To Glendive	**Length**	12.50 mi (20.12 km)
General Comments	Long secondary channels; to Glendive		

Narrative Summary

Reach D5 is located just south of Glendive. The reach is a 12.5 mile long Partially Confined Anabranching reach type, indicating the presence of forested islands with some valley wall influence on the river. The downstream end of the reach is at Black Bridge. Within Reach D5, the river flows across the Cedar Creek Anticline, which is a~115 mile long structure that extends from Glendive to Buffalo South Dakota. Oil was discovered on the anticline in 1951, and since then over a half a billion barrels of oil have been produced from 2,700 wells. As the river flows right through the anticline, the Pierre Shale becomes exposed in the right bluff line and the channel becomes more dynamic than upstream reaches. Active drill pads are located on both sides of the river; several of them are within the 100-year floodplain, and two are mapped within the CMZ.

Reach D5 has just over a mile of bank armor and most of that armor is rock riprap. There are also 1,050 feet of concrete armor and a few flow deflectors. About 640 feet of riprap was built between 2001 and 2011. The majority of the bank armor is protecting either streambank just upstream of Black Bridge. Black Bridge forms a major constriction in the river corridor and bank migration upstream of the bridge has been extensive. The bridge is oriented about 45 degrees off of the axis of the river corridor which further disrupts channel processes upstream. Just upstream of the bridge the river migrated over 1,700 feet eastward between 1950 and 2001, which is over 30 feet per year on average.

Since 1950, a side channel that is over 9,000 feet of side channel has been blocked by a dike at RM 105R. The dike crossing the head of this old channel is about 720 feet long. There are still several side channels in the reach that are perennial (flow year-round) and over a mile long.

Floodplain turnover rates have dropped in Reach D5 since 1976; prior to that time, floodplain turnover rates were about 18.5 acres per year, and since then rates have averaged 14.2 acres per year. The reduction in rates has been coupled by an increase in the extent of woody riparian vegetation of almost 300 acres.

Land use is dominated by agriculture, with 219 acres of pivot irrigation development since 1950. Some of the irrigation development took place in historic riparian areas; a total of 161 acres of riparian lands were converted for agricultural and other land uses since 1950. Development near Glendive has created about 310 acres of urban/exurban land uses in the reach. About 190 acres or 3 percent of the total CMZ has become restricted by physical features. Residential development near Glendive has encroached into the CMZ; in 2011, there were over 75 acres of urban/exurban land uses mapped within the CMZ.

Six dump sites were mapped in the reach in 2001. These sites are at RM 104L, RM 104.2L, RM 101L, RM 98L, RM 97.5L, and RM 97.1L.

One ice jam has been recorded in Reach D5. A breakup event was recorded on March 17, 2011, but no damages were recorded.

There is one pipeline crossing in the reach at RM 100. This crossing is the Poplar Pipeline owned by Bridger Pipeline, a 10 inch crude oil pipeline that ruptured in 2015. The pipeline crossing is located at the downstream end of a large forested island. Bank migration at the site has been relatively slow.

About 8 percent of the total 100-year floodplain has become isolated due to human development and most of that isolated floodplain area is behind floodplain dikes near Black Bridge. The 5-year floodplain is even more affected; 31 percent of the historic 5-year floodplain is no longer inundated at that frequency. There has been over 1,260 acres of woody riparian vegetation recruitment in the reach since 1950, indicating generation of new forest, some of which reflects encroachment due to lower flows and a shrinking river channel. The bankfull area of the channel has dropped by 255 acres since 1950. Some of that riparian expansion has been due to Russian olive colonization; there are just under 50 acres of mapped Russian olive in the Reach D5 floodplain.

Reach D5 was sampled as part of the fisheries study. A total of 33 fish species were sampled in the reach including four identified by the Montana Natural Heritage Program as a Species of Concern (SOC): the Blue Sucker, Pallid sturgeon, Sauger, and Sturgeon chub.

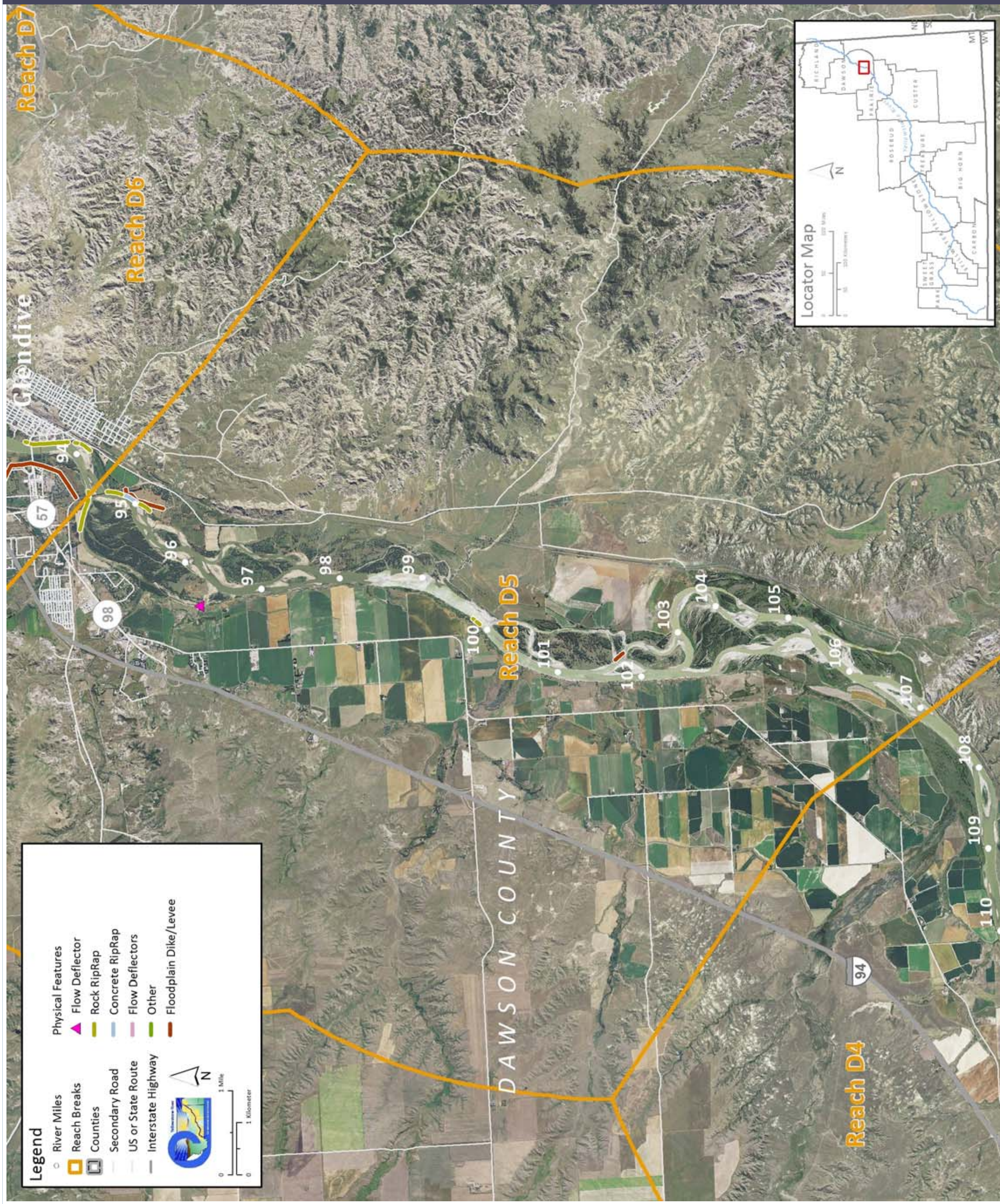
Reach D5 was sampled as part of the avian study. A total of 33 bird species were identified in the reach. One bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) was found, the Plumbeous Vireo. The Red-headed Woodpecker was also observed, which has been identified as a Species of Concern (SOC). Reach D5 has seen a decrease in the forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 86 acres per valley mile of such forest, and that number decreased to 38 acres per valley mile by 2001.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 22 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,800 cfs to 2,720 cfs with human development, a reduction of 436 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,980 cfs under unregulated conditions to 3,220 cfs, a reduction of 54 percent.

CEA-Related observations in Reach D5 include:
•Channel migration issues upstream of major constriction that is poorly aligned to corridor (Black Bridge)

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D5 include:
•Side channel reactivation at RM 104.5
•Russian olive removal
•Pipeline Crossing Practices at RM 100
•Dump site removal at RM 104L, RM 104.2L, RM 101L, RM 98L, RM 97.5L, and RM 97.1L

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	63.8	76.9

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		69,200	89,100	102,000	132,000	145,000	176,000	4,800	6,980
Regulated		54,000	73,700	86,400	113,000	124,000	150,000	2,720	3,220
% Change		-21.97%	-17.28%	-15.29%	-14.39%	-14.48%	-14.77%	-43.33%	-53.87%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Season		5%	50%	95%
Spring	Unregulated	67,300	25,100	6,900
	Regulated	52,000	15,000	5,040
	% Change	**-23%**	**-40%**	**-27%**
Summer	Unregulated	47,100	14,900	6,980
	Regulated	35,100	8,920	3,220
	% Change	**-25%**	**-40%**	**-54%**
Fall	Unregulated	9,760	5,950	2,040
	Regulated	11,200	7,440	3,580
	% Change	**15%**	**25%**	**75%**
Winter	Unregulated	14,400	5,330	2,110
	Regulated	15,000	6,490	3,430
	% Change	**4%**	**22%**	**63%**
Annual	Unregulated	49,800	8,900	2,820
	Regulated	37,100	8,010	3,650
	% Change	**-26%**	**-10%**	**29%**

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1976	USCOE	9-Oct-76	B/W	1:24,000	6329500	9580
1995	USGS DOQQ	12-Jun-96	B/W		6329500	
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6329500	4000
2004	Merrick	5/20/2004 - 6/3/04	Color	1:15,840	6329500	5070
2005	NAIP	07/31/2005	color	1-meter pixels	6329500	5280
2009	NAIP	8/10/2009	Color	1-meter pixels	6329500	13700
2009	NAIP	8/1/2009	Color	1-meter pixels	6329500	12600
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/20/2011	Color	1-meter pixels	6329500	48800
2013	NAIP	07/27/2013	color	1-meter pixels	6329500	
2013	NAIP	07/24/2013	color	1-meter pixels	6329500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	3,771	2.8%	4,409	3.3%	638
	Flow Deflectors	0	0.0%	58	0.0%	58
	Concrete RipRap	1,049	0.8%	1,049	0.8%	0
	Feature Type Totals	**4,820**	**3.6%**	**5,516**	**4.1%**	**696**
Floodplain Control						
	Transportation Encroachment	2,815	2.1%	2,815	2.1%	0
	Floodplain Dike/Levee	3,546	2.7%	2,914	2.2%	-632
	Feature Type Totals	**6,361**	**4.8%**	**5,729**	**4.3%**	**-632**
	Reach Totals	**11,181**	**8.4%**	**11,244**	**8.4%**	**63**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	0	0	0	0	0	1,050	0	0
Rock RipRap	2,801	558	328	0	0	328	0	0
Totals	**2,801**	**558**	**328**	**0**	**0**	**1,378**	**0**	**0**

Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

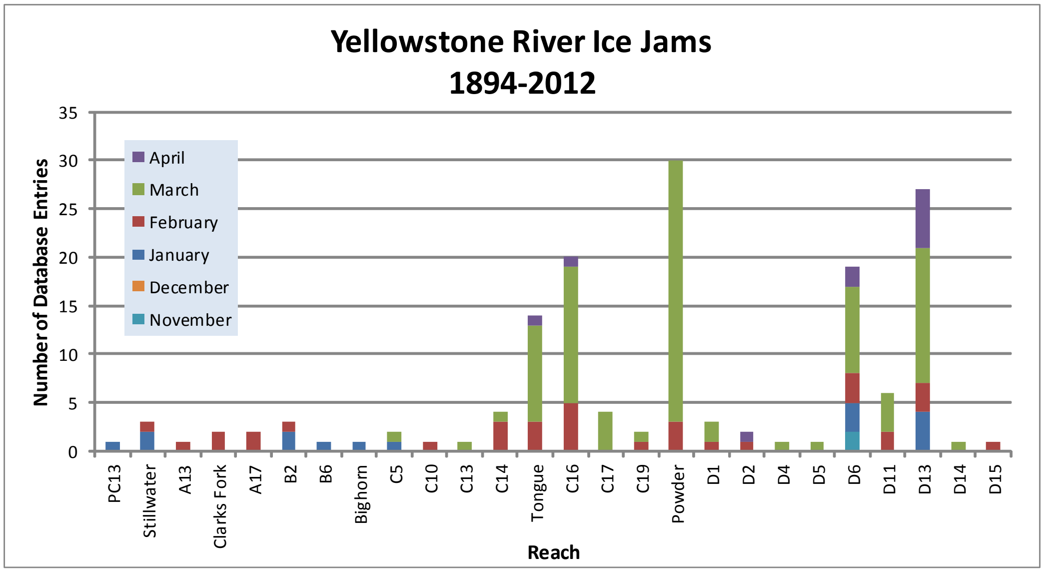
		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	6,008	6,008	6,008	6,008	6,008	6,008
	Totals	**6,008**	**6,008**	**6,008**	**6,008**	**6,008**	**6,008**
Other							
	Floodplain Dike/Levee	0	1,233	2,007	2,007	2,007	2,007
	Totals	**0**	**1,233**	**2,007**	**2,007**	**2,007**	**2,007**
Other Off Channel							
	Floodplain Dike/Levee	1,760	6,350	9,893	9,893	10,262	10,262
	Totals	**1,760**	**6,350**	**9,893**	**9,893**	**10,262**	**10,262**
Stream Stabilization							
	Rock RipRap	0	3,844	3,844	3,844	3,844	3,844
	Concrete RipRap	0	0	0	1,036	1,036	1,036
	Totals	**0**	**3,844**	**3,844**	**4,879**	**4,879**	**4,879**

Transportation Encroachment

Railroad	13,917	13,917	13,917	13,917	13,917	13,917
Other	2,394	3,975	6,409	6,409	6,409	6,409
County Road	13,899	13,899	13,899	13,899	13,899	13,899
Bridge Approach	1,707	1,707	1,707	1,707	1,707	1,707
Totals	**31,917**	**33,499**	**35,933**	**35,933**	**35,933**	**35,933**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
3/17/2011	Break-up		

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	65,846	96,726	2.47
1976	66,784	101,011	2.51
1995	59,770	114,837	2.92
2001	66,626	101,078	2.52
Change 1950 - 2001	**780**	**4,352**	**0.05**

	% Change in Braiding
1950 to 1976:	1.76%
1976 to 1995:	16.27%
1995 to 2001:	-13.84%
1950 to 2001:	1.95%

Length of Side Channels Blocked

Pre-1950s (ft)	
Post-1950s (ft)	9,066

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	60	1.9%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	101	3.1%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	88	2.7%		
Total Not Isolated (Ac)	2974		3035	
Total Floodplain Area (Ac)	3222		3571	
Total Isolated (Ac)	**248**	**7.7%**	**536**	**30.8%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	14	0	0	**14**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
481	962	5,721	190	3%	24	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	35	0.6%
RipRap			
	Irrigated	98	1.7%
Dike/Levee			
	Railroad	56	1.0%
	Totals	**190**	**3.3%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
466.3	0.0	2.2	75.2	10.7

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	25	56	100	114	0.2%	0.5%	0.9%	1.1%
	Totals	**25**	**56**	**100**	**114**	**0.2%**	**0.5%**	**0.9%**	**1.1%**
Agricultural Land									
	Non-Irrigated	6,204	5,054	4,598	4,469	58.4%	47.6%	43.3%	42.1%
	Irrigated	865	1,664	1,927	1,910	8.1%	15.7%	18.1%	18.0%
	Totals	**7,069**	**6,718**	**6,526**	**6,379**	**66.6%**	**63.3%**	**61.4%**	**60.1%**
Channel									
	Channel	3,422	3,471	3,523	3,612	32.2%	32.7%	33.2%	34.0%
	Totals	**3,422**	**3,471**	**3,523**	**3,612**	**32.2%**	**32.7%**	**33.2%**	**34.0%**
ExUrban									
	ExUrban Other	0	0	11	0	0.0%	0.0%	0.1%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	15	23	24	0.0%	0.1%	0.2%	0.2%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**15**	**34**	**24**	**0.0%**	**0.1%**	**0.3%**	**0.2%**
Transportation									
	Public Road	43	40	40	40	0.4%	0.4%	0.4%	0.4%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	63	63	62	62	0.6%	0.6%	0.6%	0.6%
	Totals	**106**	**103**	**103**	**102**	**1.0%**	**1.0%**	**1.0%**	**1.0%**
Urban									
	Urban Other	0	9	28	28	0.0%	0.1%	0.3%	0.3%
	Urban Residential	0	174	203	203	0.0%	1.6%	1.9%	1.9%
	Urban Commercial	0	7	13	20	0.0%	0.1%	0.1%	0.2%
	Urban Undeveloped	0	23	25	55	0.0%	0.2%	0.2%	0.5%
	Urban Industrial	0	46	68	85	0.0%	0.4%	0.6%	0.8%
	Totals	**0**	**258**	**337**	**391**	**0.0%**	**2.4%**	**3.2%**	**3.7%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	218	0.0%	0.0%	0.0%	3.4%	0.0%	0.0%	3.4%	3.4%
	Flood	865	1,664	1,927	1,691	12.2%	24.8%	29.5%	26.5%	12.5%	4.8%	-3.0%	14.3%
	Totals	**865**	**1,664**	**1,927**	**1,910**	**12.2%**	**24.8%**	**29.5%**	**29.9%**	**12.5%**	**4.8%**	**0.4%**	**17.7%**

Non-Irrigated

Multi-Use	5,911	4,695	4,329	4,243	83.6%	69.9%	66.3%	66.5%	-13.7%	-3.5%	0.2%	-17.1%
Hay/Pasture	294	360	269	226	4.2%	5.4%	4.1%	3.5%	1.2%	-1.2%	-0.6%	-0.6%
Totals	**6,204**	**5,054**	**4,598**	**4,469**	**87.8%**	**75.2%**	**70.5%**	**70.1%**	**-12.5%**	**-4.8%**	**-0.4%**	**-17.7%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.6	0.3	0.2	0.4	3.7	1.1	3.4	0.5	6.5
Max	174.6	163.1	121.9	127.9	121.5	182.7	61.9	175.9	181.9
Average	22.6	18.6	18.9	39.0	31.6	39.5	19.4	40.9	42.6
Sum	1,490.2	1,298.6	1,249.1	819.3	662.6	948.2	330.4	654.9	511.5

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	505.9
Channel to Riparian (acres)	800.4
Riparian Encroachment (acres)	**294.4**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	850.2
1950s Floodplain Mapped as 2011 Channel (Ac)	410.1
Total Recruitment (1950s to 2011)(Ac)	**1260.3**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	23.7	152.8	102.2	0.0	**278.7**
Acres/Valley Mile	2.2	14.3	9.5	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	48.95	2.58%	112.24	0.44	24.58	7.97

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
	✓	Bigmouth buffalo
	✓	Black bullhead
	✓	Black crappie
✓	✓	Blue sucker
	✓	Bluegill
✓	✓	Brook stickleback
		Brown trout
✓	✓	Burbot
✓	✓	Catfish species
✓	✓	Channel catfish
✓	✓	Common carp
✓	✓	Creek chub
✓	✓	Emerald shiner
✓	✓	Fathead minnow
✓	✓	Flathead chub
✓	✓	Freshwater drum
✓	✓	Goldeye
✓	✓	Green sunfish
✓	✓	Lake chub
		Largemouth bass
✓	✓	Longnose dace
✓	✓	Longnose sucker
✓	✓	Minnow species
		Mottled sculpin
		Mountain sucker
		Mountain whitefish
	✓	Northern pike
✓	✓	Northern plains killifish
	✓	Northern redbelly dace
✓	✓	Pallid sturgeon
	✓	Pumpkinseed
		Rainbow trout
✓	✓	River carpsucker
		Rock bass
✓	✓	Sand shiner
✓	✓	Sauger
✓	✓	Shorthead redhorse
	✓	Shortnose gar
✓	✓	Shovelnose sturgeon
	✓	Sicklefin chub
✓	✓	Smallmouth bass
✓	✓	Smallmouth buffalo
✓	✓	Stonecat
✓	✓	Sturgeon chub
✓	✓	Sucker species
	✓	Sunfish species
✓	✓	Walleye
✓	✓	Western silvery minnow
	✓	White bass
✓	✓	White crappie
✓	✓	White sucker
		Yellow bullhead
		Yellow perch

Low Flow Fisheries Habitat Mapping

Habitat	Bankfull (2001 Acres)	Low Flow (2001 Acres)	% of Low Flow
Scour Pool	430.8	270.5	7.7%
Rip Rap Bottom	27.7	21.7	0.6%
Terrace Pool	317.0	298.3	8.5%
Secondary Channel	280.9	177.4	5.0%
Secondary Channel (Seasonal)	483.7	320.2	9.1%
Channel Crossover	291.0	201.0	5.7%
Point Bar		116.4	3.3%
Side Bar		51.2	1.5%
Mid-channel Bar		187.1	5.3%
Island	1,691.8	1,693.7	48.0%
Dry Channel		189.8	5.4%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern Potential Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
✓	✓	American Robin		✓	Chipping Sparrow		✓	Killdeer		✓	Song Sparrow
✓	✓	American Crow	✓	✓	Clay-collared Sparrow			Lark Bunting		✓	Spotted Sandpiper
✓	✓	American Goldfinch			Cliff Swallow	✓	✓	Lark Sparrow	✓	✓	Spotted Towhee
	✓	American Kestrel	✓	✓	Common Grackle	✓	✓	Lazuli Bunting			Sharp-shinned Hawk
✓	✓	American Redstart			Common Merganser	✓	✓	Least Flycatcher			Swainson's Thrush
	✓	Bald Eagle		✓	Common Nighthawk		✓	Mallard			Sandhill Crane
		Baltimore Oriole			Common Raven			Mountain Bluebird	✓	✓	Tree Swallow
		Barn Swallow	✓	✓	Common Yellowthroat	✓	✓	Mourning Dove			Turkey Vulture
	✓	Belted Kingfisher		✓	Cooper's Hawk	✓	✓	Northern Flicker			Upland Sandpiper
	✓	Black-billed Cuckoo		✓	Dickcissel		✓	Orchard Oriole			Vesper Sparrow
	✓	Black-billed Magpie	✓	✓	Downy Woodpecker			Osprey			Violet-green Swallow
✓	✓	Black-capped Chickadee		✓	Eastern Bluebird		✓	Ovenbird	✓	✓	Warbling Vireo
	✓	Black-and-white Warbler	✓	✓	Eastern Kingbird	✓	✓	Plumbeous Vireo	✓	✓	Western Kingbird
✓	✓	Black-headed Grosbeak			Eurasian Collared-dove	✓	✓	Red-headed Woodpecker	✓	✓	Western Meadowlark
	✓	Blue Jay	✓	✓	European Starling			Red-naped Sapsucker		✓	Western Wood-pewee
	✓	Bobolink	✓	✓	Field Sparrow		✓	Red Crossbill		✓	White-breasted Nuthatch
	✓	Brewer's Blackbird		✓	Franklin's Gull		✓	Ring-necked Pheasant			White-throated Swift
✓	✓	Brown-headed Cowbird		✓	Grasshopper Sparrow		✓	Red-tailed hawk		✓	Wild Turkey
		Brown Creeper		✓	Gray Catbird		✓	Rock Dove		✓	Wood Duck
	✓	Brown Thrasher		✓	Great Blue Heron	✓	✓	Red-winged Blackbird		✓	Yellow-bellied Sapsucker
✓	✓	Bullock's Oriole		✓	Great Horned Owl	✓	✓	Red-eyed Vireo		✓	Yellow-billed Cuckoo
		Canada Goose		✓	Hairy Woodpecker		✓	Red-breasted Grosbeak	✓	✓	Yellow-breasted Chat
✓	✓	Cedar Waxwing			House Finch			Say's Phoebe			Yellow-headed Blackbird
	✓	Chimney Swift	✓	✓	House Wren		✓	Savannah Sparrow	✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.

There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

County	Dawson	**Upstream River Mile**	94.6
Classification	PCM/I: Partially confined meandering/islands	**Downstream River Mile**	89
General Location	Glendive	**Length**	5.60 mi (9.01 km)

General Comments Reach D6 is located at Glendive and provides a good example of an urbanized reach that is primarily impacted by transportation infrastructure and floodplain dikes in an area prone to severe ice jamming.

Narrative Summary

Reach D6 is located in Dawson County at Glendive. The reach is a 5.6 mile long Partly Confined Meandering reach type, extending from Black Bridge at RM 89.0 to downstream of Glendive at RM 94.6. The partial confinement is imposed by terraces and Hell Creek Formation bluff line. The reach is fairly straight, with minor bendways and several densely vegetated islands. Within Reach D6, the Yellowstone River has been directly affected by both urban/exurban development and the I-94 transportation corridor.

Reach D6 has almost a mile of bank armor including 2,930 feet of rock riprap, 1,200 feet of concrete riprap, and 760 feet of flow deflectors as mapped in 2011. About 8.3 percent of the total bankline is armored. Between 2001 and 2011, about 1,300 feet of rock riprap and 200 feet of flow deflectors were built, whereas 354 feet of concrete riprap were destroyed.

Prior to the 1950s, about three miles of side channel were blocked in the reach by physical features. Since then another three miles have been blocked such that a total of six miles of side channel have been blocked in this urbanized section of the Yellowstone River. The side channel losses occurred under the Interstate and near the mouth of Glendive Creek. In 1950, the side channel under the Interstate was almost three miles long before being blocked off.

Floodplain dikes have isolated historic floodplain area. There are 14,700 feet of floodplain dikes mapped in the reach, most of which was built between 1950 and 1976. There are also 23,736 feet of transportation encroachments. The encroachments associated with the railroad have been in place since 1950; however the length of bridge approaches increased substantially from 1950 to 1976, which is when I-94 was constructed. The large West Glendive Dike (RM 93.5) was constructed in 1957 by the US Army Corps of Engineers to protect the west Glendive area from Yellowstone River flooding.

There are five bridge crossings in Reach D6. The uppermost crossing is referred to as the BNSF “Black Bridge”, which is a 1325 foot-long steel truss bridge at RM 94.5. There is a natural gas pipeline crossing at the bridge. Just downstream at RM 93.6, the “Old Bell Street Bridge’ is a 1,290 foot long bridge that was originally built in 1894, then destroyed by ice in 1899, and rebuilt in 1924. It is currently preserved as a pedestrian bridge. Approximately 0.1 mile downstream, the Towne Street Bridge is a 1,318 foot-long steel girder/floor beam structure that was built in 1958. About 1.3 miles downstream from that structure, I-94 consists of two bridges built in 1968. These bridges are 2,013 and 1,973 feet long, and both are steel girder/floor beam structures. The I-94 bridges restrict about 200 acres of the CMZ.

Some of the most severe ice jamming in Montana occurs in Glendive. A total of 30 ice jam floods have occurred in the Glendive area since 1890 (COE, 2009). Descriptions of these and even older ice jams include loss of life (1894, 1899), bridge failure (1899) and major flooding (1899, 1936, 1969, 1986 and 1994). In 1980, FEMA concluded that the West Glendive Levee did not provide adequate protection from ice jam flooding (COE, 2009). According to the COE (2009), the majority of ice jams form downstream of the I-94 Bridge and its embankment, which acts as a flow obstruction on the left floodplain of the Yellowstone River. This embankment cuts off a side channel of the Yellowstone, "which may have historically provided a relief for floodwaters to flow around the ice jams" (COE, 2009).

Similar to many reaches on the Lower Yellowstone, the river has gotten smaller since 1950. At that time, the bankfull channel area in Reach D6 was 810 acres, and by 2001 it was 640 acres, which is a reduction of 21 percent. This has been accompanied by the encroachment of 134 acres of riparian vegetation into old channel areas. On the floodplain, however, riparian clearing has been notable; since 1950 over 400 acres of riparian vegetation was converted to another land use, which was 32 percent of the entire 1950s riparian footprint.

Floodplain turnover rates in Reach D6 have dropped from 4 acres per year prior to 1976 to 2 acres per year since then. This is also a common trend on the lower river, as the influences of bank armor and reduced flow energy have collectively slowed rates of channel change.

Land use is dominated by agriculture and urban/exurban development; although there is over 1,300 acres of urban, exurban, and transportation-related land uses, there are still over 3,100 acres of agricultural land. Most is non-irrigated, but 502 acres are in flood irrigation and 280 are in pivot. Between 1950 and 2011 approximately two square miles of land was converted to Urban and Exurban uses in the Glendive area. Much of this growth occurred in the now-leveed area on the west side of the river.

About 18 percent of the total 100-year floodplain has become isolated due to human development and most of that isolated floodplain area is behind floodplain dikes. The 5-year floodplain is even more affected; 51 percent of the historic 5-year floodplain is no longer inundated at that frequency.

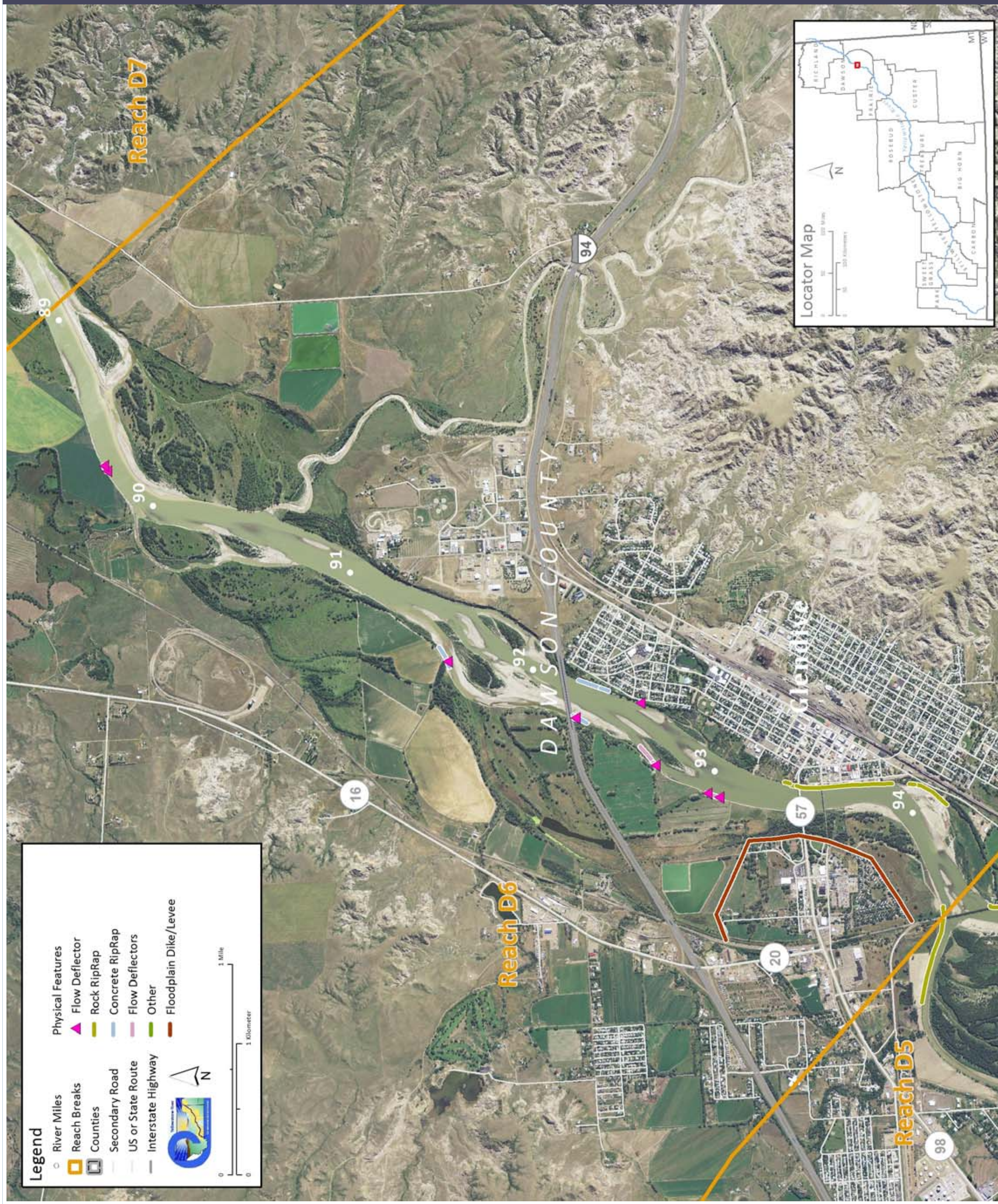
Reach D6 was sampled as part of the fisheries study. A total of 27 fish species were sampled in the reach including three identified by the Montana Natural Heritage Program as a Species of Concern (SOC): the Blue Sucker, Sauger, and Sturgeon chub.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped from 146,000 cfs pre-development to 125,000 cfs currently, which is a 14 percent reduction. The 2-year flood, which strongly influences overall channel form, has dropped by 22 percent. Summer base flows have dropped by 54 percent with human development, from 6,990 cfs to 3,210 cfs, a 54 percent reduction. In contrast, fall and winter base flows have both increased between 60 percent (winter) and 75 percent (fall). Fall and wither base flows are currently 2,030 and 2,110 cfs, respectively.

CEA-Related observations in Reach D6 include:
•Loss of side channels due to physical features
•Shrinking of channel due to flow consolidation and reduced high flows.
•Extensive transportation encroachment
•Dike construction post-1950 to facilitate urban/exurban development in West Glendive

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D6 include:
•Bank armor removal at RM 92.8L
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	58.2	89.4

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		69,400	89,400	103,000	133,000	146,000	177,000	4,790	6,990
Regulated		54,200	74,000	86,800	114,000	125,000	151,000	2,710	3,210
% Change		-21.90%	-17.23%	-15.73%	-14.29%	-14.38%	-14.69%	-43.42%	-54.08%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Season		5%	50%	95%
Spring	Unregulated	67,500	25,200	6,910
	Regulated	52,100	15,000	5,050
	% Change	**-23%**	**-40%**	**-27%**
Summer	Unregulated	47,200	14,900	6,990
	Regulated	35,200	8,930	3,210
	% Change	**-25%**	**-40%**	**-54%**
Fall	Unregulated	9,770	5,960	2,030
	Regulated	11,200	7,450	3,580
	% Change	**15%**	**25%**	**76%**
Winter	Unregulated	14,500	5,330	2,110
	Regulated	15,100	6,500	3,430
	% Change	**4%**	**22%**	**63%**
Annual	Unregulated	49,900	8,920	2,820
	Regulated	37,200	8,020	3,650
	% Change	**-25%**	**-10%**	**29%**

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1976	USCOE	9-Oct-76	B/W	1:24,000	6329500	9580
1995	USGS DOQQ	12-Jun-96	B/W		6329500	52600
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6329500	4000
2004	Merrick	5/20/04 - 6/3/2004	Color	1:15,840	6329500	5070
2005	NAIP	07/31/2005	color	1-meter pixels	6329500	5280
2005	NAIP	07/14/2005	color	1-meter pixels	6329500	15900
2009	NAIP	8/10/2009	Color	1-meter pixels	6329500	13700
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/20/2011	Color	1-meter pixels	6329500	48800
2013	NAIP	07/27/2013	color	1-meter pixels	6329500	
2013	NAIP	07/14/2013	color	1-meter pixels	6329500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	1,655	2.8%	2,933	5.0%	1,278
	Flow Deflectors	93	0.2%	330	0.6%	238
	Concrete RipRap	1,533	2.6%	1,188	2.0%	-345
	Between Flow Deflectors	496	0.8%	431	0.7%	-64
	Feature Type Totals	**3,776**	**6.4%**	**4,882**	**8.3%**	**1,106**
Floodplain Control						
	Floodplain Dike/Levee	7,743	13.2%	7,743	13.2%	0
	Feature Type Totals	**7,743**	**13.2%**	**7,743**	**13.2%**	**0**
	Reach Totals	**11,519**	**19.7%**	**12,625**	**21.5%**	**1,106**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	561	0	0	0	971	0	0	0
Flow Deflectors/Between FDs	430	0	0	0	0	0	0	0
Rock RipRap	0	0	0	1,410	0	0	0	0
Totals	**991**	**0**	**0**	**1,410**	**971**	**0**	**0**	**0**

Bankline/Floodplain Inventory: Time Series

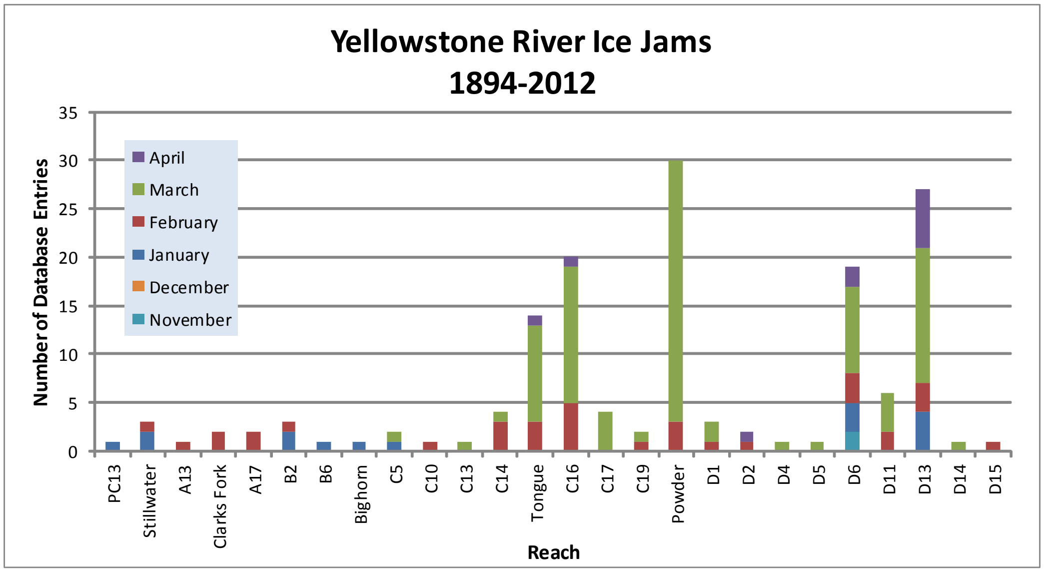
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Other							
	Floodplain Dike/Levee	688	14,720	14,720	14,720	14,720	14,720
	Totals	**688**	**14,720**	**14,720**	**14,720**	**14,720**	**14,720**
Other Off Channel							
	Floodplain Dike/Levee	0	1,505	1,505	1,505	1,505	1,505
	Totals	**0**	**1,505**	**1,505**	**1,505**	**1,505**	**1,505**
Stream Stabilization							
	Rock RipRap	728	3,060	3,060	4,156	4,156	4,156
	Flow Deflector	0	605	605	605	605	605
	Concrete RipRap	0	963	963	963	1,559	1,559
	Totals	**728**	**4,628**	**4,628**	**5,724**	**6,320**	**6,320**
Transportation Encroachment							
	Railroad	8,934	8,934	8,934	8,934	8,934	8,934

Other	0	4,542	4,542	4,542	4,542	4,542
County Road	0	2,447	2,447	2,447	2,447	2,447
Bridge Approach	1,375	7,813	7,813	7,813	7,813	7,813
Totals	**10,309**	**23,736**	**23,736**	**23,736**	**23,736**	**23,736**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
	NA	94	Death of 3 men
4/1/1904	NA	94	?
3/23/1932	NA	94	?
1/7/1934	NA	94	?
1/1/1936	NA	94	?
4/1/1943	Break-up	94	Severe flooding affecting farmers
3/19/1959	Break-up	94	25K USD
1/1/1969	NA	94	Highway, sewage pump sta., oil well supply flooded
3/15/1972	NA	93	Severe flooding
2/21/1982	NA	94	?
12/29/1992	NA	94	?
3/5/1994	NA	94	Dike nearly overtopped, 60 cattle died,
2/11/1996	Break-up	94	Flooding
2/18/1997	NA	94	?
3/9/1998	Break-up	94	Lowland flooding
3/16/2003	Break-up		
3/16/2003	Break-up		?
3/20/2009	Break-up		Unknown
3/14/2011	Break-up		
12/28/2011			

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	29,804	35,774	2.20
1976	29,529	15,343	1.52
1995	29,484	11,678	1.40
2001	29,301	13,672	1.47
Change 1950 - 2001	**-503**	**-22,102**	**-0.73**

	% Change in Braiding
1950 to 1976:	-30.94%
1976 to 1995:	-8.13%
1995 to 2001:	5.05%
1950 to 2001:	-33.35%

Length of Side Channels Blocked

Pre-1950s (ft)	16,884
Post-1950s (ft)	16,597

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	176	9.2%		
Railroad	117	6.1%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	61	3.2%		
Total Not Isolated (Ac)	1565		1126	
Total Floodplain Area (Ac)	1919		1655	
Total Isolated (Ac)	**354**	**18.4%**	**529**	**52.1%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	33	0	0	**33**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
225	451	1,819	319	18%	9	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	17	0.9%
	Non-Irrigated	29	1.6%
	Irrigated	22	1.2%
	Interstate	155	8.5%
RipRap/Flow Deflectors			
	Irrigated	7	0.4%
RipRap			
	Urban Residential	11	0.6%
	Irrigated	27	1.5%
Flow Deflectors			
	Irrigated	58	3.2%
	Totals	**326**	**17.8%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
234.0	0.0	28.5	91.6	31.7

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	27	72	75	71	0.5%	1.4%	1.4%	1.3%
	Totals	**27**	**72**	**75**	**71**	**0.5%**	**1.4%**	**1.4%**	**1.3%**
Agricultural Land									
	Non-Irrigated	2,897	2,545	2,301	2,285	54.9%	48.2%	43.6%	43.3%
	Irrigated	304	560	792	782	5.8%	10.6%	15.0%	14.8%
	Totals	**3,201**	**3,105**	**3,092**	**3,067**	**60.6%**	**58.8%**	**58.5%**	**58.1%**
Channel									
	Channel	1,380	938	738	756	26.1%	17.8%	14.0%	14.3%
	Totals	**1,380**	**938**	**738**	**756**	**26.1%**	**17.8%**	**14.0%**	**14.3%**
ExUrban									
	ExUrban Other	0	64	143	143	0.0%	1.2%	2.7%	2.7%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	60	60	60	0.0%	1.1%	1.1%	1.1%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	24	28	28	0.0%	0.4%	0.5%	0.5%
	Totals	**0**	**148**	**231**	**231**	**0.0%**	**2.8%**	**4.4%**	**4.4%**
Transportation									
	Public Road	65	67	67	67	1.2%	1.3%	1.3%	1.3%
	Interstate	0	58	58	58	0.0%	1.1%	1.1%	1.1%
	Railroad	45	45	45	45	0.9%	0.9%	0.9%	0.9%
	Totals	**110**	**170**	**170**	**170**	**2.1%**	**3.2%**	**3.2%**	**3.2%**
Urban									
	Urban Other	150	39	97	97	2.8%	0.7%	1.8%	1.8%
	Urban Residential	198	410	432	435	3.7%	7.8%	8.2%	8.2%
	Urban Commercial	79	116	115	115	1.5%	2.2%	2.2%	2.2%
	Urban Undeveloped	43	51	81	90	0.8%	1.0%	1.5%	1.7%
	Urban Industrial	93	233	251	251	1.8%	4.4%	4.7%	4.7%
	Totals	**563**	**849**	**976**	**988**	**10.7%**	**16.1%**	**18.5%**	**18.7%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	91	279	0.0%	0.0%	2.9%	9.1%	0.0%	2.9%	6.2%	9.1%
	Flood	304	560	701	502	9.5%	18.0%	22.7%	16.4%	8.5%	4.6%	-6.3%	6.9%
	Totals	**304**	**560**	**792**	**782**	**9.5%**	**18.0%**	**25.6%**	**25.5%**	**8.5%**	**7.6%**	**-0.1%**	**16.0%**

Non-Irrigated												
Multi-Use	2,272	1,881	1,984	2,060	71.0%	60.6%	64.1%	67.2%	-10.4%	3.6%	3.0%	-3.8%
Hay/Pasture	625	664	317	225	19.5%	21.4%	10.3%	7.3%	1.9%	-11.1%	-2.9%	-12.2%
Totals	**2,897**	**2,545**	**2,301**	**2,285**	**90.5%**	**82.0%**	**74.4%**	**74.5%**	**-8.5%**	**-7.6%**	**0.1%**	**-16.0%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.5	0.3	0.8	0.4	4.5	1.6	2.7	6.1	0.8
Max	313.7	161.4	77.1	138.3	59.0	53.0	142.4	47.9	79.5
Average	27.9	15.5	13.9	24.6	22.8	26.5	29.2	13.3	13.9
Sum	669.5	603.5	403.8	393.2	250.5	345.1	233.5	106.4	139.3

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	94.7
Channel to Riparian (acres)	229.0
Riparian Encroachment (acres)	**134.4**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	283.9
1950s Floodplain Mapped as 2011 Channel (Ac)	0.9
Total Recruitment (1950s to 2011)(Ac)	**284.8**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	47.0	88.9	18.6	0.0	**154.5**
Acres/Valley Mile	9.1	17.1	3.6	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	7.08	0.49%	9.11	0.64	2.11	0.76

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
☐	☑	Bigmouth buffalo
☐	☑	Black bullhead
☐	☑	Black crappie
☑	☑	Blue sucker
☑	☑	Bluegill
☑	☑	Brook stickleback
☐	☐	Brown trout
☑	☑	Burbot
☐	☑	Catfish species
☑	☑	Channel catfish
☑	☑	Common carp
☑	☑	Creek chub
☑	☑	Emerald shiner
☑	☑	Fathead minnow
☑	☑	Flathead chub
☑	☑	Freshwater drum
☑	☑	Goldeye
☐	☑	Green sunfish
☐	☑	Lake chub
☐	☐	Largemouth bass
☑	☑	Longnose dace
☑	☑	Longnose sucker
☐	☑	Minnow species
☐	☐	Mottled sculpin
☐	☐	Mountain sucker
☐	☐	Mountain whitefish
☑	☑	Northern pike
☐	☑	Northern plains killifish
☑	☑	Northern redbelly dace
☐	☑	Pallid sturgeon
☑	☑	Pumpkinseed
☐	☐	Rainbow trout
☑	☑	River carpsucker
☐	☐	Rock bass
☑	☑	Sand shiner
☑	☑	Sauger
☑	☑	Shorthead redhorse
☐	☑	Shortnose gar
☑	☑	Shovelnose sturgeon
☐	☑	Sicklefin chub
☐	☑	Smallmouth bass
☐	☑	Smallmouth buffalo
☑	☑	Stonecat
☑	☑	Sturgeon chub
☐	☑	Sucker species
☐	☑	Sunfish species
☑	☑	Walleye
☑	☑	Western silvery minnow
☐	☑	White bass
☑	☑	White crappie
☑	☑	White sucker
☐	☐	Yellow bullhead
☐	☐	Yellow perch

Low Flow Fisheries Habitat Mapping

Habitat	Bankfull (2001 Acres)	Low Flow (2001 Acres)	% of Low Flow
Scour Pool	238.7	199.2	27.0%
Rip Rap Margin	18.8	5.5	0.7%
Terrace Pool	153.0	120.1	16.3%
Secondary Channel	52.0	65.6	8.9%
Secondary Channel (Seasonal)	53.4	48.1	6.5%
Channel Crossover	126.1	80.5	10.9%
Point Bar		37.4	5.1%
Side Bar		51.5	7.0%
Mid-channel Bar		14.6	2.0%
Island	97.5	104.8	14.2%
Dry Channel		9.7	1.3%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

Yellowstone River Reach Narratives — Reach D7

County	Dawson	**Upstream River Mile**	89
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	81.4
General Location	Downstream of Glendive	**Length**	7.60 mi (12.23 km)

General Comments

Narrative Summary

Reach D7 is located just downstream of Glendive. It is 7.6 miles long and is a Partially Confined Anabranching (PCA) reach type, including some valley wall influence as well as numerous forested islands. These reach types tend to be relatively dynamic with high rates of channel change through time. The Stipek Fishing Access Site is located in the middle portion of the reach.

No bank armor has been mapped in Reach D7, and no side channels have been blocked by dikes. About two miles of transportation encroachment by the railroad was mapped in Reach D7, all of which was in place by 1950.

Similar to many reaches in the Lower Yellowstone Valley, the river channel in Reach D7 has gotten smaller since 1950. The channel contracted by about 121 acres in this reach since 1950, and about 150 acres of riparian vegetation has encroached into old channel areas. This pattern has been consistent in the lower river, and relates primarily to a reduction in flows due to human development. Floodplain turnover rates have dropped from 8.9 acres per year pre-1976 to5.4 acres per year post-1976.

Even though no side channels have been intentionally blocked, Reach D7 has lost about 3,800 feet of side channel length since 1950. This is likely due to passive loss caused by a reduction in high flows. Lower flows have also resulted in the isolation of 48 percent of the historic 5-year floodplain.

Land use is predominantly agricultural, with about 258 acres of pivot irrigation development since 1950. There are 27 acres of pivot irrigation and 21 acres of exurban land uses in the Channel Migration Zone. Two dump sites have been mapped on the right bank at RM 84R and RM 85.9R.

There are 7.4 acres of mapped Russian olive in the reach.

Reach D7 was part of the avian study. A total of 43 species were identified in the reach, including the Ovenbird, which has been identified by the Montana Natural Heritage Program as a Potential Special Concern. The Black-billed Cuckoo and Red-headed Woodpecker were also identified, both of which are Species of Concern.

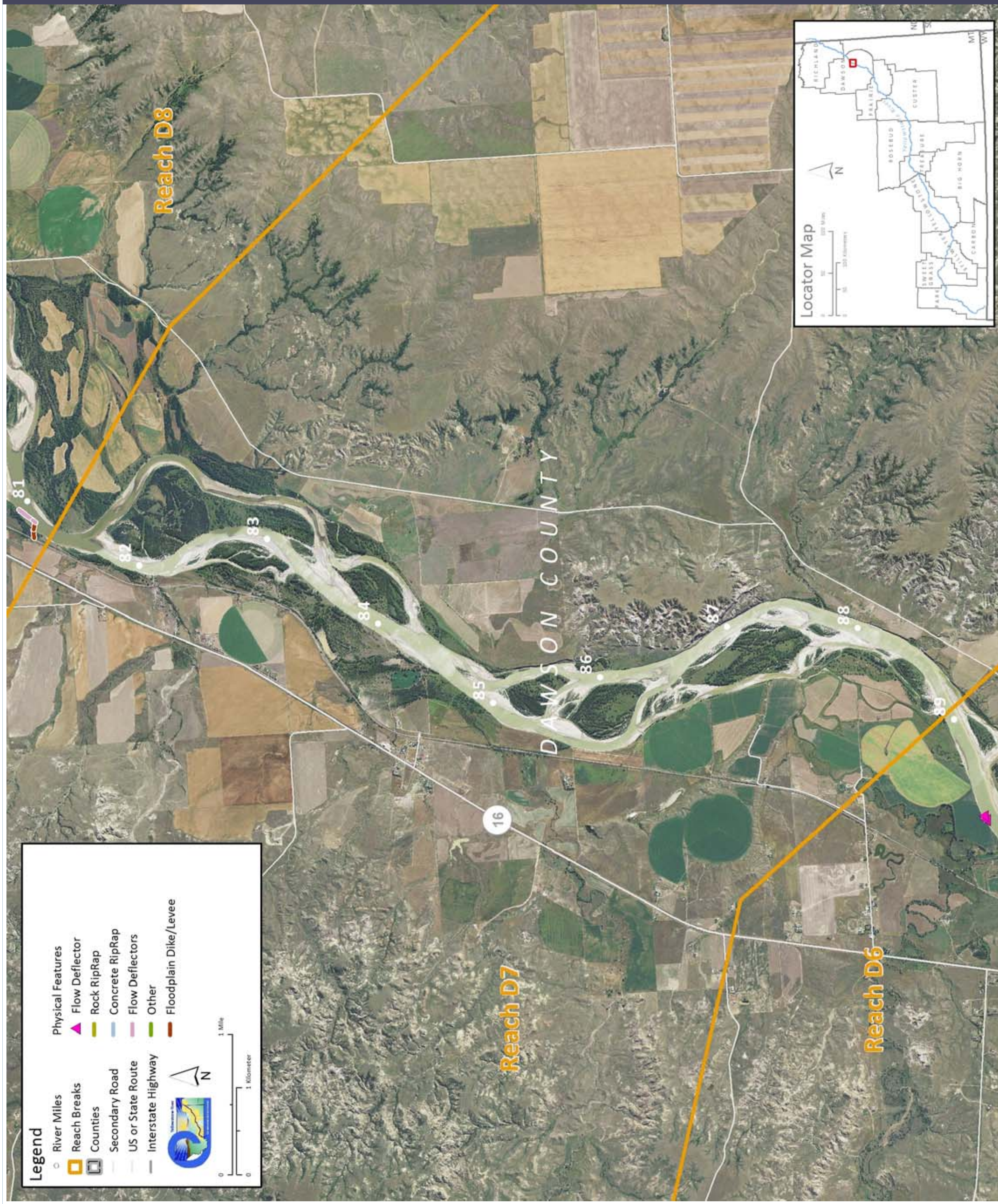
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The magnitude of the 100-year flood is now 127,000 cfs, which 12 percent lower than it was pre-development (145,000 cfs). The 2-year flood, which strongly influences overall channel form, has dropped by 22 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,700 cfs to 2,600 cfs with human development, a reduction of 45 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,890 cfs under unregulated conditions to 3,110 cfs under regulated conditions, a reduction of 55 percent.

Seasonal low flows have increased by 78 percent in the winter and 62 percent in the fall. Both fall and winter base flows are currently about 3,500 cfs.

CEA-Related observations in Reach D7 include:
•Passive loss of side channels with flow alterations

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D7 include:
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	50.6	95.0

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		69,500	89,600	103,000	133,000	145,000	176,000	4,700	6,890
Regulated		54,200	74,200	87,200	115,000	127,000	153,000	2,600	3,110
% Change		-22.01%	-17.19%	-15.34%	-13.53%	-12.41%	-13.07%	-44.68%	-54.86%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	67,500	25,100	6,960
	Regulated	52,100	14,900	5,080
	% Change	**-23%**	**-41%**	**-27%**
Summer	Unregulated	47,300	14,900	6,890
	Regulated	35,200	8,820	3,110
	% Change	**-26%**	**-41%**	**-55%**
Fall	Unregulated	9,800	5,940	2,010
	Regulated	11,200	7,430	3,570
	% Change	**14%**	**25%**	**78%**
Winter	Unregulated	14,800	5,380	2,120
	Regulated	15,400	6,550	3,440
	% Change	**4%**	**22%**	**62%**
Annual	Unregulated	49,900	8,900	2,820
	Regulated	37,200	8,020	3,620
	% Change	**-25%**	**-10%**	**28%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1976	USCOE	9-Oct-76	B/W	1:24,000	6329500	9580
1995	USGS DOQQ	12-Jun-96	B/W		6329500	52600
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6329500	4000
2004	Merrick	5/20/2004 - 6/3/04	Color	1:15,840	6329500	5070
2005	NAIP	07/14/2005	color	1-meter pixels	6329500	15900
2009	NAIP	8/10/2009	Color	1-meter pixels	6329500	13700
2009	NAIP	7/11/2009	Color	1-meter pixels	6329500	32600
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/20/2011	Color	1-meter pixels	6329500	48800
2013	NAIP	07/27/2013	color	1-meter pixels	6329500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

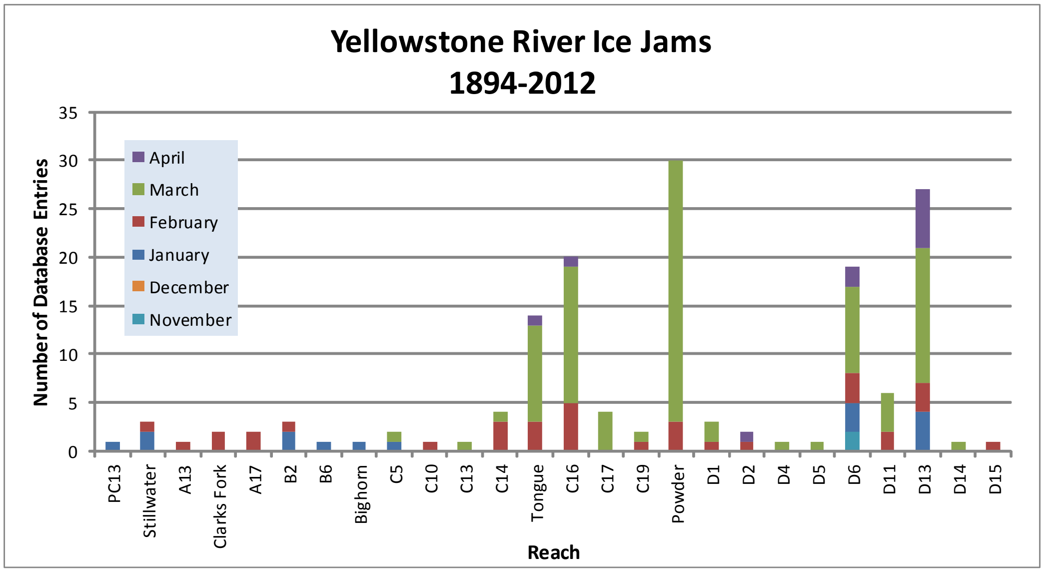
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

Feature Class	Feature Type	Sum of Feature Length (ft) 1950	1976	1995	2001	2004	2005
Transportation Encroachment							
	Railroad	12,529	12,529	12,529	12,529	12,529	12,529
	Totals	**12,529**	**12,529**	**12,529**	**12,529**	**12,529**	**12,529**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	43,833	59,956	2.37	1950 to 1976:	1.78%
1976	39,713	55,991	2.41	1976 to 1995:	3.49%
1995	40,102	59,914	2.49	1995 to 2001:	-4.10%
2001	40,314	56,108	2.39	1950 to 2001:	1.01%
Change 1950 - 2001	**-3,519**	**-3,848**	**0.02**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	44	2.4%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1762		1532	
Total Floodplain Area (Ac)	1806		1928	
Total Isolated (Ac)	**44**	**2.4%**	**395**	**47.9%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	2	0	0	**2**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
341	682	2,811	6	0%	127	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	6	0.2%
	Totals	**6**	**0.2%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
180.4	2.2	27.3	20.7	9.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	29	64	81	84	0.4%	0.9%	1.2%	1.2%
	Totals	**29**	**64**	**81**	**84**	**0.4%**	**0.9%**	**1.2%**	**1.2%**
Agricultural Land									
	Non-Irrigated	4,756	4,485	3,767	3,629	70.5%	66.5%	55.9%	53.8%
	Irrigated	0	182	876	992	0.0%	2.7%	13.0%	14.7%
	Totals	**4,756**	**4,668**	**4,644**	**4,621**	**70.5%**	**69.2%**	**68.9%**	**68.5%**
Channel									
	Channel	1,869	1,918	1,881	1,899	27.7%	28.4%	27.9%	28.2%
	Totals	**1,869**	**1,918**	**1,881**	**1,899**	**27.7%**	**28.4%**	**27.9%**	**28.2%**
ExUrban									
	ExUrban Other	0	0	24	23	0.0%	0.0%	0.4%	0.3%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	3	22	26	0.0%	0.0%	0.3%	0.4%
	Totals	**0**	**3**	**46**	**49**	**0.0%**	**0.0%**	**0.7%**	**0.7%**
Transportation									
	Public Road	57	59	59	59	0.8%	0.9%	0.9%	0.9%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	31	31	31	31	0.5%	0.5%	0.5%	0.5%
	Totals	**88**	**90**	**90**	**90**	**1.3%**	**1.3%**	**1.3%**	**1.3%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	26	26	0.0%	0.0%	0.5%	0.6%	0.0%	0.5%	0.0%	0.6%
	Pivot	0	0	0	258	0.0%	0.0%	0.0%	5.6%	0.0%	0.0%	5.6%	5.6%
	Flood	0	182	851	708	0.0%	3.9%	18.3%	15.3%	3.9%	14.4%	-3.0%	15.3%
	Totals	**0**	**182**	**876**	**992**	**0.0%**	**3.9%**	**18.9%**	**21.5%**	**3.9%**	**15.0%**	**2.6%**	**21.5%**

Non-Irrigated

Multi-Use	3,714	2,925	2,899	2,816	78.1%	62.7%	62.4%	61.0%	-15.4%	-0.2%	-1.5%	-17.1%
Hay/Pasture	1,043	1,560	868	812	21.9%	33.4%	18.7%	17.6%	11.5%	-14.7%	-1.1%	-4.3%
Totals	**4,756**	**4,485**	**3,767**	**3,629**	**######**	**96.1%**	**81.1%**	**78.5%**	**-3.9%**	**-15.0%**	**-2.6%**	**-21.5%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.2	0.5	0.9	0.1	0.7	2.7	2.7	2.0	1.4
Max	107.9	88.8	35.3	153.3	159.7	298.9	53.7	26.1	48.2
Average	13.4	13.5	8.2	44.6	35.5	66.1	15.1	11.3	16.8
Sum	617.6	619.7	318.1	757.7	815.5	1,123.3	136.3	67.6	134.1

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	209.9
Channel to Riparian (acres)	359.2
Riparian Encroachment (acres)	**149.4**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	366.8
1950s Floodplain Mapped as 2011 Channel (Ac)	53.7
Total Recruitment (1950s to 2011)(Ac)	**420.6**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	28.9	72.3	47.1	0.0	**148.2**
Acres/Valley Mile	4.2	10.6	6.9	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	7.44	0.21%	1.67	0.00	4.97	1.12

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	349.7	212.3	11.3%
Bluff Pool	138.1	163.2	8.7%
Secondary Channel	186.2	130.8	7.0%
Secondary Channel (Seasonal)	262.8	190.1	10.1%
Channel Crossover	164.3	124.7	6.6%
Point Bar		89.5	4.8%
Side Bar		69.3	3.7%
Mid-channel Bar		60.2	3.2%
Island	778.5	789.4	42.0%
Dry Channel		47.6	2.5%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern Potential Species of Concern

Reach	Region	Species
✓	✓	American Robin
✓	✓	American Crow
✓	✓	American Goldfinch
✓	✓	American Kestrel
✓	✓	American Redstart
✓	✓	Bald Eagle
		Baltimore Oriole
		Barn Swallow
	✓	Belted Kingfisher
✓	✓	Black-billed Cuckoo
✓	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
	✓	Black-and-white Warbler
✓	✓	Black-headed Grosbeak
	✓	Blue Jay
	✓	Bobolink
✓	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
		Brown Creeper
	✓	Brown Thrasher
	✓	Bullock's Oriole
		Canada Goose
✓	✓	Cedar Waxwing
	✓	Chimney Swift
✓	✓	Chipping Sparrow
	✓	Clay-collared Sparrow
		Cliff Swallow
✓	✓	Common Grackle
		Common Merganser
	✓	Common Nighthawk
		Common Raven
✓	✓	Common Yellowthroat
	✓	Cooper's Hawk
	✓	Dickcissel
✓	✓	Downy Woodpecker
	✓	Eastern Bluebird
✓	✓	Eastern Kingbird
		Eurasian Collared-dove
✓	✓	European Starling
	✓	Field Sparrow
	✓	Franklin's Gull
	✓	Grasshopper Sparrow
	✓	Gray Catbird
	✓	Great Blue Heron
	✓	Great Horned Owl
✓	✓	Hairy Woodpecker
		House Finch
✓	✓	House Wren
✓	✓	Killdeer
		Lark Bunting
✓	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
	✓	Mallard
		Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
✓	✓	Orchard Oriole
		Osprey
✓	✓	Ovenbird
	✓	Plumbeous Vireo
✓	✓	Red-headed Woodpecker
		Red-naped Sapsucker
	✓	Red Crossbill
✓	✓	Ring-necked Pheasant
	✓	Red-tailed hawk
	✓	Rock Dove
	✓	Red-winged Blackbird
✓	✓	Red-eyed Vireo
	✓	Red-breasted Grosbeak
		Say's Phoebe
	✓	Savannah Sparrow
✓	✓	Song Sparrow
✓	✓	Spotted Sandpiper
✓	✓	Spotted Towhee
		Sharp-shinned Hawk
		Swainson's Thrush
		Sandhill Crane
✓	✓	Tree Swallow
		Turkey Vulture
		Upland Sandpiper
		Vesper Sparrow
		Violet-green Swallow
✓	✓	Warbling Vireo
✓	✓	Western Kingbird
✓	✓	Western Meadowlark
✓	✓	Western Wood-pewee
✓	✓	White-breasted Nuthatch
		White-throated Swift
	✓	Wild Turkey
	✓	Wood Duck
	✓	Yellow-bellied Sapsucker
	✓	Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
		Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.

There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

County	Dawson	**Upstream River Mile**	81.4
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	71.1
General Location	Intake	**Length**	10.30 mi (16.58 km)
General Comments	To Intake		

Narrative Summary

Reach D8 is located in Dawson County, and includes Intake Diversion Dam. The reach is a Partly Confined Anabranching reach type, indicating distinct side channels around forested islands, and some valley wall influence on the active channel. Intake Diversion Dam is located on the lower end of the reach at RM 73.

The primary form of bank stabilization in Reach D8 is rock riprap, with 4,576 feet or 1.9 percent of the total bankline mapped as armored in 2011. All of the bank armor in Reach D8 is protecting either Intake Diversion or the railroad grade; the majority (3,178 feet) is against the rail line. In the uppermost part of the reach at RM 81L, over 1,500 feet of flow deflectors were flanked between 2001 and 2011. At RM 77L, the river has flanked two sections of rock riprap protecting the rail line, forming two large scallops in the bank that currently threaten to undermine the toe of the railroad embankment.

The largest diversion dam on the Yellowstone River is Intake Diversion Dam at RM 73. Construction of the dam began in 1905, in response to authorization under the Reclamation Act of 1902 (http://www.fws.gov/yellowstonerivercoordinator/Intake.html). Intake Dam was completed in 1911 and is used to irrigate 50,000 acres of land in eastern Montana and western North Dakota. The original dam crest was 12 feet above the river bed; and the structure stretches 700 feet across the river. With a diversion capacity of 1,200 cfs, it feeds Intake Canal and a ~225 mile network of lateral canals that distribute water to approximately 500 farms. Fish passage issues at this structure are currently being addressed by the Bureau Reclamation, US Army Corps of Engineers, MT Fish Wildlife and Parks, US Fish and Wildlife Service, and Lower Yellowstone Irrigation District.

Reach D8 has lost almost three miles of side channel length since 1950, and none of this loss is attributable to floodplain dikes. Similar to other reaches in the lower Yellowstone River valley, side channel loss has occurred to both intentional blockages, as well as lost connectivity due to flow alterations. Flow alterations have also resulted in lost connectivity to the 5-year floodplain; development in the basin has resulted in the isolation of 58 percent of the historic 5-year floodplain.

There are 110 acres of sprinkler irrigation and 19 acres of exurban land in the Channel Migration Zone in Reach D8, making these areas especially susceptible to threats of river erosion.

There has been a net increase of woody riparian vegetation in Reach D8 of approximately 210 acres since 1950, indicating riparian colonization of open gravel bars and channel margins.

There are about 10 acres of mapped Russian olive in the reach.

Reach D8 was sampled as part of the avian study. A total of 21 species were identified in the reach, including the Red-headed Woodpecker, which is a Species of Concern.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The magnitude of the 100-year flood is now 128,000 cfs, which 12 percent lower than it was pre-development (145,000 cfs). The 2-year flood, which strongly influences overall channel form, has dropped by 22 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,630 cfs to 2,520 cfs with human development, a reduction of 46 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,810 cfs under unregulated conditions to 3,030 cfs under regulated conditions, a reduction of 55 percent.

Seasonal low flows have increased by 78 percent in the winter and 62 percent in the fall. Both fall and winter base flows are currently about 3,500 cfs.

CEA-Related observations in Reach D8 include:
•Passive loss of side channels with flow alterations
•Low avian species richness
•Passive loss of 5-year floodplain area

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D8 include:
•Flanked bank armor removal at RM 77L and RM 81L
•Fish Passage Practices at Intake Diversion Dam (RM 73)
•Watercraft Passage PRACTICE at Intake Diversion Dam (RM 73)
•Irrigation Structure Management at Intake Diversion Dam (RM 73)
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	40.3	102.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		69,500	89,700	103,000	132,000	145,000	175,000	4,630	6,810
Regulated		54,200	74,300	87,400	116,000	128,000	155,000	2,520	3,030
% Change		-22.01%	-17.17%	-15.15%	-12.12%	-11.72%	-11.43%	-45.57%	-55.51%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	67,500	25,000	7,000
	Regulated	52,100	14,800	5,100
	% Change	**-23%**	**-41%**	**-27%**
Summer	Unregulated	47,400	14,800	6,810
	Regulated	35,200	8,740	3,030
	% Change	**-26%**	**-41%**	**-56%**
Fall	Unregulated	9,820	5,920	2,000
	Regulated	11,200	7,410	3,560
	% Change	**14%**	**25%**	**78%**
Winter	Unregulated	15,000	5,410	2,120
	Regulated	15,600	6,580	3,450
	% Change	**4%**	**22%**	**63%**
Annual	Unregulated	49,800	8,890	2,820
	Regulated	37,100	8,010	3,590
	% Change	**-26%**	**-10%**	**27%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1976	USCOE	9-Oct-76	B/W	1:24,000	6329500	9580
1995	USGS DOQQ	8/8/96 - 6/12/96	B/W		6329500	52600
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6329500	4000
2004	Merrick	5/20/2004 - 6/3/04	Color	1:15,840	6329500	5070
2005	NAIP	07/14/2005	color	1-meter pixels	6329500	15900
2009	NAIP	7/11/2009	Color	1-meter pixels	6329500	32600
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/21/2011	Color	1-meter pixels	6329500	46600
2011	NAIP	7/20/2011	Color	1-meter pixels	6329500	48800
2013	NAIP	07/27/2013	color	1-meter pixels	6329500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	4,140	3.9%	4,576	4.3%	435
	Flow Deflectors	122	0.1%	0	0.0%	-122
	Between Flow Deflectors	641	0.6%	0	0.0%	-641
	Feature Type Totals	**4,904**	**4.6%**	**4,576**	**4.3%**	**-328**
Floodplain Control						
	Floodplain Dike/Levee	519	0.5%	319	0.3%	-200
	Feature Type Totals	**519**	**0.5%**	**319**	**0.3%**	**-200**
	Reach Totals	**5,423**	**5.1%**	**4,895**	**4.6%**	**-528**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	0	764	0	0	0	0	0	0
Rock RipRap	0	0	961	0	0	3,178	0	0
Totals	**0**	**764**	**961**	**0**	**0**	**3,178**	**0**	**0**

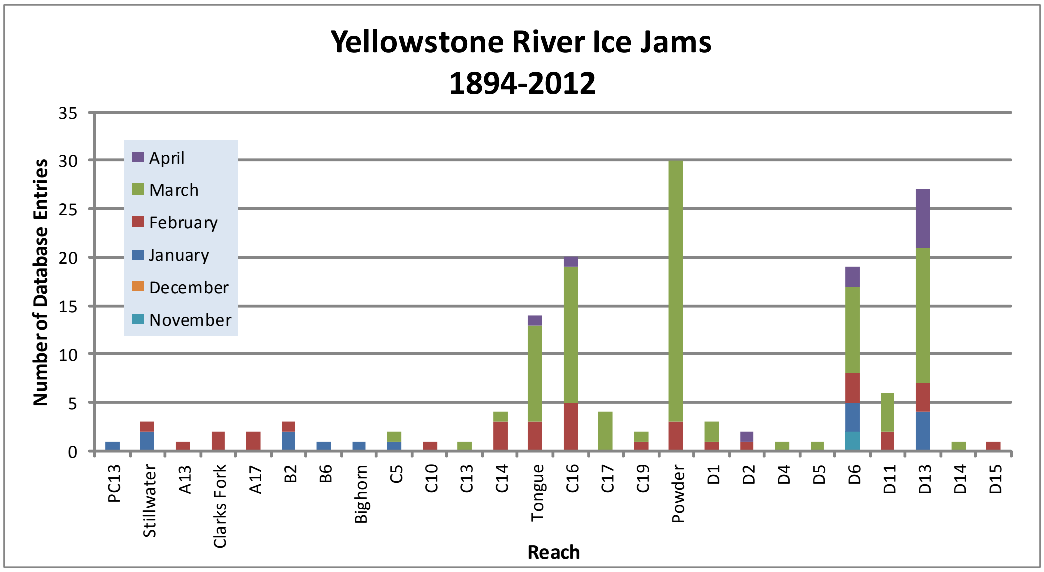
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	In Channel Diversion	669	669	669	669	669	669
	Floodplain Dike/Levee	5,268	5,268	5,268	5,268	5,268	5,268
	Totals	**5,936**	**5,936**	**5,936**	**5,936**	**5,936**	**5,936**
Other Off Channel							
	Floodplain Dike/Levee	478	478	478	478	478	478
	Totals	**478**	**478**	**478**	**478**	**478**	**478**
Stream Stabilization							
	Rock RipRap	962	2,562	2,562	3,433	3,433	3,433
	Flow Deflector	0	0	0	0	734	734
	Totals	**962**	**2,562**	**2,562**	**3,433**	**4,168**	**4,168**
Transportation Encroachment							
	Railroad	10,300	10,300	10,300	10,300	10,300	10,300
	County Road	4,206	4,206	4,206	4,206	4,206	4,206
	Totals	**14,506**	**14,506**	**14,506**	**14,506**	**14,506**	**14,506**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	55,112	53,812	1.98	1950 to 1976:	9.19%
1976	54,712	63,359	2.16	1976 to 1995:	5.96%
1995	53,646	69,029	2.29	1995 to 2001:	-1.33%
2001	53,643	67,389	2.26	1950 to 2001:	14.16%
Change 1950 - 2001	**-1,470**	**13,577**	**0.28**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	61	1.6%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	38	1.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	3746		1729	
Total Floodplain Area (Ac)	3845		2342	
Total Isolated (Ac)	**99**	**2.6%**	**613**	**57.7%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	0	**0**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
274	549	4,130	44	1%	1,067	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Railroad	28	0.5%
	Totals	**28**	**0.5%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
213.7	109.0	0.0	19.4	16.4

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	29	29	29	29	0.3%	0.3%	0.3%	0.3%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	11	54	86	88	0.1%	0.6%	1.0%	1.0%
	Totals	**40**	**83**	**115**	**117**	**0.5%**	**1.0%**	**1.3%**	**1.4%**
Agricultural Land									
	Non-Irrigated	5,278	5,010	4,746	4,639	61.4%	58.3%	55.2%	54.0%
	Irrigated	51	331	592	615	0.6%	3.8%	6.9%	7.2%
	Totals	**5,329**	**5,341**	**5,338**	**5,253**	**62.0%**	**62.1%**	**62.1%**	**61.1%**
Channel									
	Channel	3,070	3,024	2,971	3,054	35.7%	35.2%	34.6%	35.5%
	Totals	**3,070**	**3,024**	**2,971**	**3,054**	**35.7%**	**35.2%**	**34.6%**	**35.5%**
ExUrban									
	ExUrban Other	0	0	21	21	0.0%	0.0%	0.2%	0.2%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	17	36	36	36	0.2%	0.4%	0.4%	0.4%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**17**	**36**	**56**	**56**	**0.2%**	**0.4%**	**0.7%**	**0.7%**
Transportation									
	Public Road	95	69	71	71	1.1%	0.8%	0.8%	0.8%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	45	44	44	44	0.5%	0.5%	0.5%	0.5%
	Totals	**140**	**113**	**116**	**116**	**1.6%**	**1.3%**	**1.3%**	**1.3%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	7	8	157	164	0.1%	0.2%	2.9%	3.1%	0.0%	2.8%	0.2%	3.0%
	Pivot	0	0	157	180	0.0%	0.0%	2.9%	3.4%	0.0%	2.9%	0.5%	3.4%
	Flood	44	322	278	271	0.8%	6.0%	5.2%	5.2%	5.2%	-0.8%	-0.1%	4.3%
	Totals	**51**	**331**	**592**	**615**	**1.0%**	**6.2%**	**11.1%**	**11.7%**	**5.2%**	**4.9%**	**0.6%**	**10.7%**

Non-Irrigated												
Multi-Use	4,732	4,285	3,801	3,693	88.8%	80.2%	71.2%	70.3%	-8.6%	-9.0%	-0.9%	-18.5%
Hay/Pasture	546	724	945	946	10.2%	13.6%	17.7%	18.0%	3.3%	4.1%	0.3%	7.8%
Totals	**5,278**	**5,010**	**4,746**	**4,639**	**99.0%**	**93.8%**	**88.9%**	**88.3%**	**-5.2%**	**-4.9%**	**-0.6%**	**-10.7%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.2	1.2	1.3	3.4	2.8	3.0	2.7	8.5	2.1
Max	186.4	197.8	271.2	110.6	400.1	301.4	100.9	103.7	106.7
Average	31.7	23.8	43.9	41.4	70.6	51.6	26.9	53.9	29.1
Sum	1,491.5	1,240.2	1,184.8	994.8	1,483.3	1,444.0	430.9	269.3	203.4

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	172.8
Channel to Riparian (acres)	380.3
Riparian Encroachment (acres)	**207.5**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	403.3
1950s Floodplain Mapped as 2011 Channel (Ac)	32.0
Total Recruitment (1950s to 2011)(Ac)	**435.2**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	13.7	46.2	24.3	0.0	**84.2**
Acres/Valley Mile	2.0	6.6	3.5	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	9.70	0.18%	1.32	0.04	5.84	1.92

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	**Bankfull**	**Low Flow**	**% of Low Flow**
Scour Pool	501.8	362.7	12.2%
Rip Rap Bottom	20.9	21.3	0.7%
Rip Rap Margin	64.5	59.0	2.0%
Terrace Pool	51.4	43.2	1.5%
Secondary Channel	106.4	42.3	1.4%
Secondary Channel (Seasonal)	198.9	173.7	5.8%
Channel Crossover	288.7	258.5	8.7%
Point Bar		86.4	2.9%
Side Bar		76.7	2.6%
Mid-channel Bar		40.6	1.4%
Island	1,695.9	1,695.9	57.0%
Dry Channel		71.7	2.4%
Dam Influenced	51.5	43.9	1.5%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern | Potential Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
✔	✔	American Robin	☐	✔	Chipping Sparrow	☐	✔	Killdeer	☐	✔	Song Sparrow
☐	✔	American Crow	☐	✔	Clay-collared Sparrow	☐	☐	Lark Bunting	☐	✔	Spotted Sandpiper
✔	✔	American Goldfinch	☐	☐	Cliff Swallow	☐	✔	Lark Sparrow	☐	✔	Spotted Towhee
✔	✔	American Kestrel	✔	✔	Common Grackle	✔	✔	Lazuli Bunting	☐	☐	Sharp-shinned Hawk
☐	✔	American Redstart	☐	☐	Common Merganser	✔	✔	Least Flycatcher	☐	☐	Swainson's Thrush
☐	✔	Bald Eagle	☐	✔	Common Nighthawk	☐	✔	Mallard	☐	☐	Sandhill Crane
☐	☐	Baltimore Oriole	☐	☐	Common Raven	☐	☐	Mountain Bluebird	☐	✔	Tree Swallow
☐	☐	Barn Swallow	✔	✔	Common Yellowthroat	✔	✔	Mourning Dove	☐	☐	Turkey Vulture
☐	✔	Belted Kingfisher	☐	✔	Cooper's Hawk	✔	✔	Northern Flicker	☐	☐	Upland Sandpiper
☐	✔	Black-billed Cuckoo	☐	✔	Dickcissel	☐	✔	Orchard Oriole	☐	☐	Vesper Sparrow
☐	✔	Black-billed Magpie	✔	✔	Downy Woodpecker	☐	☐	Osprey	☐	☐	Violet-green Swallow
✔	✔	Black-capped Chickadee	☐	✔	Eastern Bluebird	☐	✔	Ovenbird	✔	✔	Warbling Vireo
☐	✔	Black-and-white Warbler	✔	✔	Eastern Kingbird	☐	✔	Plumbeous Vireo	☐	✔	Western Kingbird
☐	✔	Black-headed Grosbeak	☐	☐	Eurasian Collared-dove	✔	✔	Red-headed Woodpecker	☐	✔	Western Meadowlark
☐	✔	Blue Jay	✔	✔	European Starling	☐	☐	Red-naped Sapsucker	✔	✔	Western Wood-pewee
☐	✔	Bobolink	☐	✔	Field Sparrow	☐	✔	Red Crossbill	☐	✔	White-breasted Nuthatch
✔	✔	Brewer's Blackbird	☐	✔	Franklin's Gull	☐	✔	Ring-necked Pheasant	☐	☐	White-throated Swift
☐	✔	Brown-headed Cowbird	☐	✔	Grasshopper Sparrow	☐	✔	Red-tailed hawk	☐	✔	Wild Turkey
☐	☐	Brown Creeper	☐	✔	Gray Catbird	☐	✔	Rock Dove	☐	✔	Wood Duck
☐	✔	Brown Thrasher	☐	✔	Great Blue Heron	✔	✔	Red-winged Blackbird	☐	✔	Yellow-bellied Sapsucker
☐	✔	Bullock's Oriole	☐	✔	Great Horned Owl	✔	✔	Red-eyed Vireo	☐	✔	Yellow-billed Cuckoo
☐	☐	Canada Goose	☐	✔	Hairy Woodpecker	☐	✔	Red-breasted Grosbeak	☐	✔	Yellow-breasted Chat
✔	✔	Cedar Waxwing	☐	☐	House Finch	☐	☐	Say's Phoebe	☐	☐	Yellow-headed Blackbird
☐	✔	Chimney Swift	✔	✔	House Wren	☐	✔	Savannah Sparrow	☐	✔	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.

There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

Yellowstone River Reach Narratives — Reach D9

County	Dawson	**Upstream River Mile**	71.1
Classification	PCM/I: Partially confined meandering/islands	**Downstream River Mile**	67.8
General Location	Downstream of Intake	**Length**	3.30 mi (5.31 km)
General Comments	Downstream of Intake		

Narrative Summary

Reach D9 is located in Dawson County and starts 1 mile below the Intake Diversion Dam. The reach is a 3.3 mile long Partly Confined Meandering with Islands (PCM/I) reach type, indicating a single-threaded channel with vegetated islands and some valley wall influence on the active channel. This reach is currently the most upstream reach that fully supports pallid sturgeon and paddlefish in the watershed.

This reach has almost no bank armor. There are almost three miles of floodplain dikes associated with irrigation, and two miles of transportation encroachment associated with the railroad grade.

By 1950 almost three miles of side channel had been blocked in Reach D9, with another mile blocked since then. At RM 68.8L, discreet dikes block a side channel that remains within the riparian area, suggesting some potential for restoration.

There is one small rapid in the reach at RM 69.8 where it appears that a bedrock shelf is exposed in the riverbed.

Isolation of the 100 year floodplain has resulted from both physical features on the floodplain as well as reduced flows with human development. In Reach D9, 170 acres of the floodplain, which is 15 percent of the historic floodplain area, is no longer inundated at that frequency. Most of this area isolated is out in flood irrigated fields on the west floodplain. The 5-year floodplain, which has become smaller primarily due to flow alterations, has lost 161 acres or 50 percent of its original footprint.

Land use is predominantly agricultural, with about 183 acres of pivot irrigation development since 1950. There are a total of 19 acres of pivot-irrigated ground within the Channel Migration Zone (CMZ), making these fields especially prone to river erosion.

Reach D9 has seen an increase in the amount of forest area considered at low risk of cowbird parasitism. In 1950, there were 42.3 acres per valley mile of such forest, and by 2001, that number had increased to 79.7 acres per valley mile.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The magnitude of the 100-year flood is now 128,000 cfs, which is 12 percent lower than it was pre-development (145,000 cfs). The 2-year flood, which strongly influences overall channel form, has dropped by 22 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,630 cfs to 2,460 cfs with human development, a reduction of 47 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,760 cfs under unregulated conditions to 2,980 cfs under regulated conditions, a reduction of 56 percent.

In the fall and winter, low flows are typically around 3,500 cfs, which is 60-75 percent higher than historic flow conditions.

CEA-Related observations in Reach D9 include:
•Floodplain isolation due to flow alterations and agricultural dikes
•Side channel blockages

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D9 include:
•Side channel reactivation at RM 68.8L
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	37.0	112.9

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		69,600	89,800	103,000	132,000	145,000	175,000	4,630	6,760
Regulated		54,200	74,400	87,600	116,000	128,000	156,000	2,460	2,980
% Change		-22.13%	-17.15%	-14.95%	-12.12%	-11.72%	-10.86%	-46.87%	-55.92%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	67,500	25,000	7,030
	Regulated	52,100	14,800	5,110
	% Change	**-23%**	**-41%**	**-27%**
Summer	Unregulated	47,400	14,800	6,760
	Regulated	35,200	8,680	2,980
	% Change	**-26%**	**-41%**	**-56%**
Fall	Unregulated	9,830	5,900	1,990
	Regulated	11,200	7,400	3,550
	% Change	**14%**	**25%**	**78%**
Winter	Unregulated	15,200	5,440	2,120
	Regulated	15,800	6,610	3,460
	% Change	**4%**	**22%**	**63%**
Annual	Unregulated	49,800	8,880	2,820
	Regulated	37,100	8,010	3,580
	% Change	**-26%**	**-10%**	**27%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1976	USCOE	9-Oct-76	B/W	1:24,000	6329500	9580
1995	USGS DOQQ	8-Aug-96	B/W		6329500	10300
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6329500	4000
2004	Merrick	3-Jun-04	Color	1:15,840	6329500	9950
2005	NAIP	07/14/2005	color	1-meter pixels	6329500	15900
2009	NAIP	7/11/2009	Color	1-meter pixels	6329500	32600
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/21/2011	Color	1-meter pixels	6329500	46600
2013	NAIP	07/27/2013	color	1-meter pixels	6329500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Flow Deflectors	0	0.0%	45	0.1%	45
	Feature Type Totals		**0.0%**	**45**	**0.1%**	
Other In Channel						
	Bedrock Outcrop	417	1.1%	417	1.1%	0
	Feature Type Totals	**417**	**1.1%**	**417**	**1.1%**	**0**
	Reach Totals	**417**	**1.1%**	**462**	**1.3%**	**45**

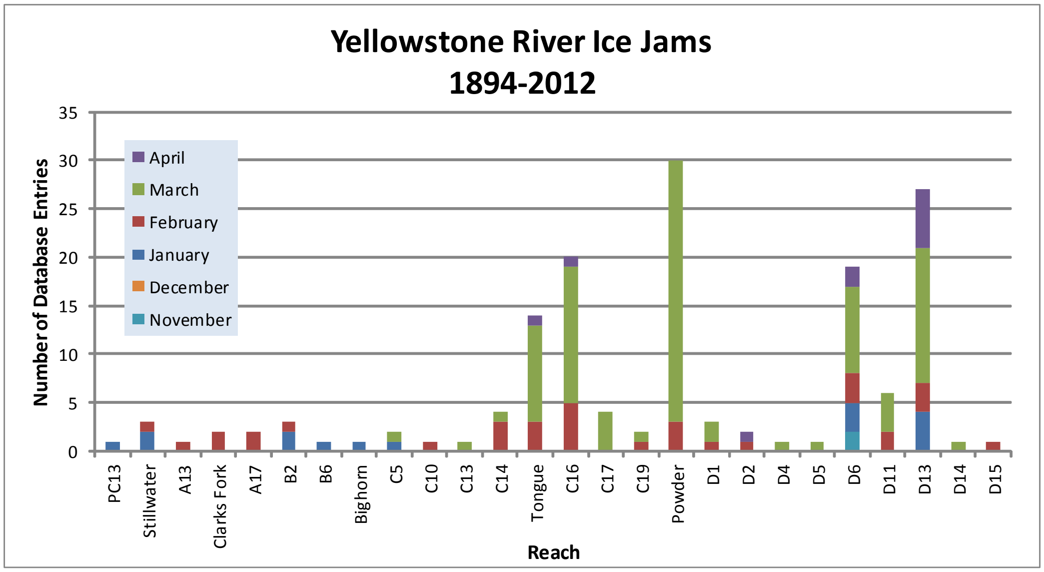
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	15,737	15,737	15,737	15,737	15,737	15,737
	Totals	**15,737**	**15,737**	**15,737**	**15,737**	**15,737**	**15,737**
Other Off Channel							
	Floodplain Dike/Levee	0	1,038	1,038	1,038	1,038	1,038
	Totals	**0**	**1,038**	**1,038**	**1,038**	**1,038**	**1,038**
Transportation Encroachment							
	Railroad	11,580	11,580	11,580	11,580	11,580	11,580
	Totals	**11,580**	**11,580**	**11,580**	**11,580**	**11,580**	**11,580**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	17,273	14,070	1.81	1950 to 1976:	-12.98%
1976	17,792	10,303	1.58	1976 to 1995:	23.66%
1995	18,461	17,589	1.95	1995 to 2001:	2.57%
2001	18,461	18,515	2.00	1950 to 2001:	10.38%
Change 1950 - 2001	**1,188**	**4,445**	**0.19**		

Length of Side Channels Blocked

Pre-1950s (ft)	14,796
Post-1950s (ft)	6,635

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	137	12.4%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	33	3.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	940		578	
Total Floodplain Area (Ac)	1111		739	
Total Isolated (Ac)	**170**	**15.3%**	**161**	**50.4%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	0	**0**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
344	688	1,094	0	0%	310	0	0%

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
29.0	0.0	19.2	0.0	0.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	65	65	65	65	1.7%	1.7%	1.7%	1.7%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	16	16	13	13	0.4%	0.4%	0.3%	0.3%
	Totals	**81**	**81**	**78**	**78**	**2.1%**	**2.1%**	**2.1%**	**2.1%**
Agricultural Land									
	Non-Irrigated	2,248	2,244	2,221	2,211	59.1%	59.0%	58.4%	58.1%
	Irrigated	760	886	891	891	20.0%	23.3%	23.4%	23.4%
	Totals	**3,008**	**3,130**	**3,112**	**3,102**	**79.1%**	**82.3%**	**81.8%**	**81.6%**
Channel									
	Channel	679	557	578	588	17.9%	14.7%	15.2%	15.5%
	Totals	**679**	**557**	**578**	**588**	**17.9%**	**14.7%**	**15.2%**	**15.5%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	19	19	19	19	0.5%	0.5%	0.5%	0.5%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	16	16	16	16	0.4%	0.4%	0.4%	0.4%
	Totals	**35**	**35**	**35**	**35**	**0.9%**	**0.9%**	**0.9%**	**0.9%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	183	183	0.0%	0.0%	5.9%	5.9%	0.0%	5.9%	0.0%	5.9%
	Flood	760	886	708	708	25.3%	28.3%	22.8%	22.8%	3.0%	-5.5%	0.1%	-2.5%
	Totals	**760**	**886**	**891**	**891**	**25.3%**	**28.3%**	**28.6%**	**28.7%**	**3.0%**	**0.3%**	**0.1%**	**3.4%**

Non-Irrigated												
Multi-Use	1,963	2,017	1,992	1,989	65.3%	64.4%	64.0%	64.1%	-0.8%	-0.4%	0.1%	-1.2%
Hay/Pasture	285	228	228	222	9.5%	7.3%	7.3%	7.2%	-2.2%	0.1%	-0.2%	-2.3%
Totals	**2,248**	**2,244**	**2,221**	**2,211**	**74.7%**	**71.7%**	**71.4%**	**71.3%**	**-3.0%**	**-0.3%**	**-0.1%**	**-3.4%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.9	1.9	1.8	4.6	3.5	2.9	5.3	9.5	5.2
Max	97.0	44.4	29.9	144.7	168.6	521.6	39.3	68.7	5.2
Average	22.9	12.4	10.5	52.2	40.5	52.1	15.5	27.0	5.2
Sum	480.6	286.1	146.3	417.5	526.9	781.5	77.3	108.0	5.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	112.1
Channel to Riparian (acres)	147.4
Riparian Encroachment (acres)	**35.3**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	147.4
1950s Floodplain Mapped as 2011 Channel (Ac)	31.2
Total Recruitment (1950s to 2011)(Ac)	**178.6**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	1.9	21.8	18.1	0.0	**41.9**
Acres/Valley Mile	0.6	7.2	6.0	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	1.04	0.05%	0.21	0.00	0.44	0.07

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	160.1	82.7	14.3%
Bluff Pool	112.3	76.9	13.3%
Secondary Channel		8.8	1.5%
Secondary Channel (Seasonal)	84.8	57.5	9.9%
Channel Crossover	57.4	61.4	10.6%
Point Bar		47.2	8.2%
Side Bar		21.4	3.7%
Mid-channel Bar		2.6	0.5%
Island	159.7	159.4	27.6%
Dry Channel		60.5	10.5%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

Yellowstone River Reach Narratives — Reach D10

County	Dawson	**Upstream River Mile**	67.8
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	56.3
General Location	Lowermost Dawson County, Richland County	**Length**	11.50 mi (18.51 km)
General Comments	Vegatated islands		

Narrative Summary

Reach D10 is located in lowermost Dawson County and extends into upper Richland County. The reach is an 11.5 mile long Partially Confined Anabranching (PCA) reach type, indicating some valley wall influence and numerous forested islands.

In 2011 there were just about 730 feet of rock riprap in the reach armoring 0.6 percent of the total stream bank. Prior to that some armor had been lost; between 2001 and 2011, almost 500 feet of rock riprap and 1,050 feet of concrete riprap were destroyed. Some of the greatest damage was at RM 64.2L, where several hundred feet of flow deflectors were flanked, and now are in the river over 100 feet off of the bank. The remaining bank protection in this area continues to flank. Another is at RM 60, where the flanking of concrete riprap has been followed by over 200 feet of erosion behind the original armor.

Similar to many reaches in the Lower Yellowstone Valley, the river channel in Reach D10 has gotten smaller since 1950. The channel contracted by about 404 acres in this reach since 1950, and about 406 acres of riparian vegetation has encroached into old channel areas. This pattern has been consistent in the lower river, and relates primarily to a reduction in flows due to human development. The encroachment was at the expense of open gravel bars; between 1950 and 2001, the reach lost 151 acres of mid-channel bar habitat. Floodplain turnover rates have dropped as well; prior to 1976 measured floodplain turnover rates in this reach were 13.9 acres per year, and post-1976 rages were 7.0 acres per year.

Reach D10 has a relatively high concentration of mapped wetlands; the NWI mapping shows a total of 278 acres of mapped wetland, much of which is emergent marsh and wet meadow.

Land use is dominated by agriculture, with 230 acres of pivot irrigation development since 1950. Some of the irrigation development took place in historic riparian areas; a total of 457 acres of riparian lands were converted for agricultural and other land uses since 1950. This equates to 15 percent of the entire 1950 riparian footprint. There are 97 acres of land under pivot irrigation within the Channel Migration Zone (CMZ) of the river, making these areas especially prone to river erosion.

About 38 percent of the historic 5-year floodplain has become isolated, primarily due to flow alterations.

Reach D10 was sampled as part of the avian study. A total of 57 species were identified in the reach, indicating relatively high bird species richness on the Yellowstone River. Four species identified are considered Potential Species of Concern (PSOC) by the Montana Natural Heritage Center: The Black and White Warbler, Dickscissel, Ovenbird, and Plumbeous Vireo. The Red-headed Woodpecker was also identified which is a Species of Concern. Similar to Reach D9 upstream, Reach D10 has seen an increase in the amount of forest area considered at low risk of cowbird parasitism. In 1950, there were 92 acres per valley mile of such forest, and by 2001, that number had increased to 112 acres per valley mile.

There are about 12 acres of mapped Russian olive in the reach.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 22 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,850 cfs to 2,810 cfs with human development, a reduction of 43 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,940 cfs under unregulated conditions to 3,270 cfs under regulated conditions, a reduction of 53 percent.

CEA-Related observations in Reach D10 include:
•Armor flanking and accelerated erosion behind

Recommended Practices (May include Yellowstone River Recommended Practices--YRRPs) for Reach D10 include:
•Removal of flanked armor at RM 60 and RM 64.2L
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	25.5	116.2

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		69,700	90,000	103,000	132,000	144,000	173,000	4,450	6,620
Regulated		54,200	74,700	88,100	118,000	130,000	159,000	2,310	2,840
% Change		-22.24%	-17.00%	-14.47%	-10.61%	-9.72%	-8.09%	-48.09%	-57.10%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Season		5%	50%	95%
Spring	Unregulated	67,400	24,900	7,100
	Regulated	52,000	14,600	5,150
	% Change	**-23%**	**-41%**	**-27%**
Summer	Unregulated	47,500	14,700	6,620
	Regulated	35,300	8,540	2,840
	% Change	**-26%**	**-42%**	**-57%**
Fall	Unregulated	9,870	5,870	1,970
	Regulated	11,300	7,370	3,530
	% Change	**14%**	**26%**	**79%**
Winter	Unregulated	15,600	5,500	2,130
	Regulated	16,200	6,670	3,480
	% Change	**4%**	**21%**	**63%**
Annual	Unregulated	49,800	8,860	2,830
	Regulated	37,000	8,000	3,530
	% Change	**-26%**	**-10%**	**25%**

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1976	MDT	28-Oct-77	B/W	1:12,000	6329500	5800
1995	USGS DOQQ	7/9/96 - 7/15/96 - 8/8/96	B/W		6329500	35000
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6329500	4000
2004	Merrick	3-Jun-04	Color	1:15,840	6329500	9950
2005	NAIP	07/14/2005	color	1-meter pixels	6329500	15900
2009	NAIP	7/11/2009	Color	1-meter pixels	6329500	32600
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/21/2011	Color	1-meter pixels	6329500	46600
2013	NAIP	07/19/2013	color	1-meter pixels	6329500	
2013	NAIP	07/27/2013	color	1-meter pixels	6329500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	1,175	1.0%	728	0.6%	-447
	Concrete RipRap	1,051	0.9%	0	0.0%	-1,051
	Feature Type Totals	**2,226**	**1.9%**	**728**	**0.6%**	**-1,498**
Other In Channel						
	Bedrock Outcrop	787	0.7%	787	0.7%	0
	Feature Type Totals	**787**	**0.7%**	**787**	**0.7%**	**0**
	Reach Totals	**3,012**	**2.5%**	**1,515**	**1.3%**	**-1,498**

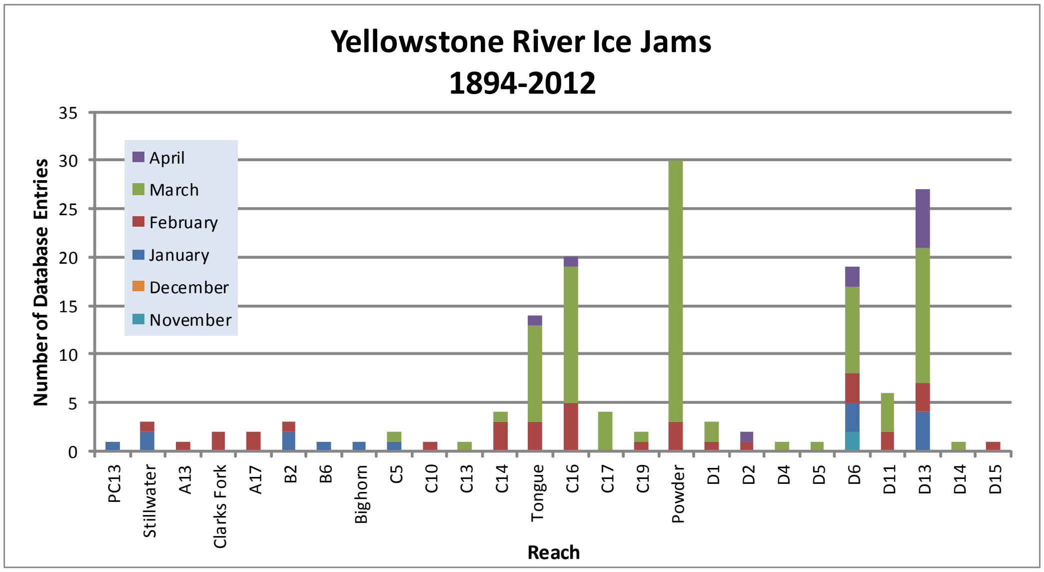
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	1,050	0	0	0	0	0	0	0
Rock RipRap	0	1,174	0	0	0	0	0	0
Totals	**1,050**	**1,174**	**0**	**0**	**0**	**0**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	59,537	92,853	2.56	1950 to 1976:	-4.18%
1976	60,364	87,686	2.45	1976 to 1995:	-3.62%
1995	61,165	83,424	2.36	1995 to 2001:	11.88%
2001	59,913	98,546	2.64	1950 to 2001:	3.33%
Change 1950 - 2001	**376**	**5,693**	**0.09**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	94	1.9%		
Agriculture (generally relates to field boundaries)	13	0.3%		
Agriculture (isloated by canal or large ditch)	121	2.5%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	423	8.7%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	4236		2758	
Total Floodplain Area (Ac)	4887		3576	
Total Isolated (Ac)	**651**	**13.3%**	**818**	**38.3%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	121	0	0	**121**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
526	1,051	4,753	95	2%	233	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	8	0.2%
RipRap			
	Non-Irrigated	44	0.9%
	Totals	**52**	**1.0%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
540.6	0.0	96.5	5.7	1.8

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	26	26	26	26	0.3%	0.3%	0.3%	0.3%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	18	18	29	26	0.2%	0.2%	0.4%	0.3%
	Totals	**44**	**44**	**55**	**53**	**0.5%**	**0.5%**	**0.7%**	**0.6%**
Agricultural Land									
	Non-Irrigated	3,863	4,018	4,158	3,825	47.1%	49.0%	50.7%	46.6%
	Irrigated	723	1,130	1,533	1,505	8.8%	13.8%	18.7%	18.3%
	Totals	**4,586**	**5,148**	**5,692**	**5,330**	**55.9%**	**62.8%**	**69.4%**	**65.0%**
Channel									
	Channel	3,546	2,979	2,424	2,788	43.2%	36.3%	29.6%	34.0%
	Totals	**3,546**	**2,979**	**2,424**	**2,788**	**43.2%**	**36.3%**	**29.6%**	**34.0%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	5	6	6	0.0%	0.1%	0.1%	0.1%
	Totals	**0**	**5**	**6**	**6**	**0.0%**	**0.1%**	**0.1%**	**0.1%**
Transportation									
	Public Road	5	5	5	5	0.1%	0.1%	0.1%	0.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	21	21	21	21	0.3%	0.3%	0.3%	0.3%
	Totals	**26**	**26**	**26**	**26**	**0.3%**	**0.3%**	**0.3%**	**0.3%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	232	229	0.0%	0.0%	4.1%	4.3%	0.0%	4.1%	0.2%	4.3%
	Flood	723	1,130	1,301	1,275	15.8%	21.9%	22.9%	23.9%	6.2%	0.9%	1.1%	8.2%
	Totals	**723**	**1,130**	**1,533**	**1,505**	**15.8%**	**21.9%**	**26.9%**	**28.2%**	**6.2%**	**5.0%**	**1.3%**	**12.5%**

Non-Irrigated													
	Multi-Use	3,442	3,567	3,909	3,594	75.1%	69.3%	68.7%	67.4%	-5.8%	-0.6%	-1.2%	-7.6%
	Hay/Pasture	421	452	250	231	9.2%	8.8%	4.4%	4.3%	-0.4%	-4.4%	-0.1%	-4.8%
	Totals	**3,863**	**4,018**	**4,158**	**3,825**	**84.2%**	**78.1%**	**73.1%**	**71.8%**	**-6.2%**	**-5.0%**	**-1.3%**	**-12.5%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.8	0.3	0.1	0.3	1.3	1.6	0.0	7.0	5.6
Max	148.9	156.3	88.8	213.5	693.9	870.0	80.0	32.7	42.8
Average	27.8	13.6	16.9	48.9	59.9	53.4	20.8	17.3	24.7
Sum	1,251.2	680.8	796.1	1,760.9	1,797.3	2,083.2	228.3	138.1	172.7

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	343.0
Channel to Riparian (acres)	748.9
Riparian Encroachment (acres)	**405.9**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	758.1
1950s Floodplain Mapped as 2011 Channel (Ac)	164.3
Total Recruitment (1950s to 2011)(Ac)	**922.3**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	21.6	136.8	120.4	0.0	**278.7**
Acres/Valley Mile	2.3	14.7	12.9	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	11.90	0.22%	5.79	0.02	5.83	2.33

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	307.2	219.2	9.0%
Rip Rap Bottom	115.7	62.0	2.6%
Bluff Pool	188.0	134.9	5.6%
Secondary Channel	103.1	73.2	3.0%
Secondary Channel (Seasonal)	449.9	415.5	17.1%
Channel Crossover	275.2	148.3	6.1%
Point Bar		248.7	10.3%
Side Bar		20.5	0.8%
Mid-channel Bar		21.3	0.9%
Island	985.0	989.2	40.8%
Dry Channel		91.3	3.8%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern

Potential Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
✓	✓	American Robin		✓	Chipping Sparrow		✓	Killdeer	✓	✓	Song Sparrow
✓	✓	American Crow	✓	✓	Clay-collared Sparrow			Lark Bunting	✓	✓	Spotted Sandpiper
✓	✓	American Goldfinch			Cliff Swallow	✓	✓	Lark Sparrow	✓	✓	Spotted Towhee
✓	✓	American Kestrel	✓	✓	Common Grackle	✓	✓	Lazuli Bunting			Sharp-shinned Hawk
✓	✓	American Redstart			Common Merganser	✓	✓	Least Flycatcher			Swainson's Thrush
✓	✓	Bald Eagle	✓	✓	Common Nighthawk		✓	Mallard			Sandhill Crane
✓	✓	Baltimore Oriole			Common Raven			Mountain Bluebird	✓	✓	Tree Swallow
		Barn Swallow	✓	✓	Common Yellowthroat	✓	✓	Mourning Dove			Turkey Vulture
✓	✓	Belted Kingfisher	✓	✓	Cooper's Hawk	✓	✓	Northern Flicker			Upland Sandpiper
	✓	Black-billed Cuckoo	✓	✓	Dickcissel		✓	Orchard Oriole			Vesper Sparrow
✓	✓	Black-billed Magpie	✓	✓	Downy Woodpecker			Osprey			Violet-green Swallow
✓	✓	Black-capped Chickadee	✓	✓	Eastern Bluebird	✓	✓	Ovenbird	✓	✓	Warbling Vireo
✓	✓	Black-and-white Warbler	✓	✓	Eastern Kingbird	✓	✓	Plumbeous Vireo	✓	✓	Western Kingbird
✓	✓	Black-headed Grosbeak			Eurasian Collared-dove	✓	✓	Red-headed Woodpecker	✓	✓	Western Meadowlark
✓	✓	Blue Jay	✓	✓	European Starling			Red-naped Sapsucker	✓	✓	Western Wood-pewee
	✓	Bobolink	✓	✓	Field Sparrow		✓	Red Crossbill	✓	✓	White-breasted Nuthatch
✓	✓	Brewer's Blackbird		✓	Franklin's Gull	✓	✓	Ring-necked Pheasant			White-throated Swift
✓	✓	Brown-headed Cowbird	✓	✓	Grasshopper Sparrow	✓	✓	Red-tailed hawk	✓	✓	Wild Turkey
		Brown Creeper	✓	✓	Gray Catbird		✓	Rock Dove		✓	Wood Duck
✓	✓	Brown Thrasher		✓	Great Blue Heron	✓	✓	Red-winged Blackbird		✓	Yellow-bellied Sapsucker
✓	✓	Bullock's Oriole		✓	Great Horned Owl	✓	✓	Red-eyed Vireo	✓	✓	Yellow-billed Cuckoo
		Canada Goose	✓	✓	Hairy Woodpecker		✓	Red-breasted Grosbeak	✓	✓	Yellow-breasted Chat
✓	✓	Cedar Waxwing			House Finch			Say's Phoebe			Yellow-headed Blackbird
	✓	Chimney Swift	✓	✓	House Wren		✓	Savannah Sparrow	✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

County	Richland	**Upstream River Mile**	56.3
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	49.9
General Location	Savage; Elk Island	**Length**	6.40 mi (10.30 km)
General Comments	Elk Island: Very wide riparian; marked change in channel course since 1981 geologic map base		

Narrative Summary

Reach D11 is 10.3 miles long, located near Savage and Elk Island. It is a Partially Confined Anabranching reach type (PCA) indicating distinct side channels around vegetated islands with some valley wall influences. The valley wall is comprised of Tertiary-age Fort Union Formation, and a distinct terrace surface borders the active stream corridor. Fort Union Formation rocks are exposed on a right bank bluff on the downstream end of the reach.

There is no mapped bank armor in Reach D11. Prior to 1950, however, about three miles of side channel had been blocked, mostly around Elk Island.

The most striking change in Reach D11 since 1950 is the encroachment of riparian vegetation onto old sand bars. Between 1950 and 2001, the size of the channel has dropped by 313 acres, and there has been 294 acres of riparian encroachment into old channel areas. Much of this encroachment converted open sand bars into forested islands. There has been a loss of over 100 acres of sand bar since 1950. This change has resulted in a conversion of almost 7 miles low flow channels around gravel bars to anabranching side channels around islands.

Reach D11 has had six ice jams-related floods reported since 1943. They all occurred in February or March, and several of them reported flood damages.

Approximately 36 percent of the historic 5-year floodplain has become isolated, largely due to flow alterations.

Land use in the reach is dominated by flood irrigation.

There are about 32 acres of Russian olive mapped in the reach.

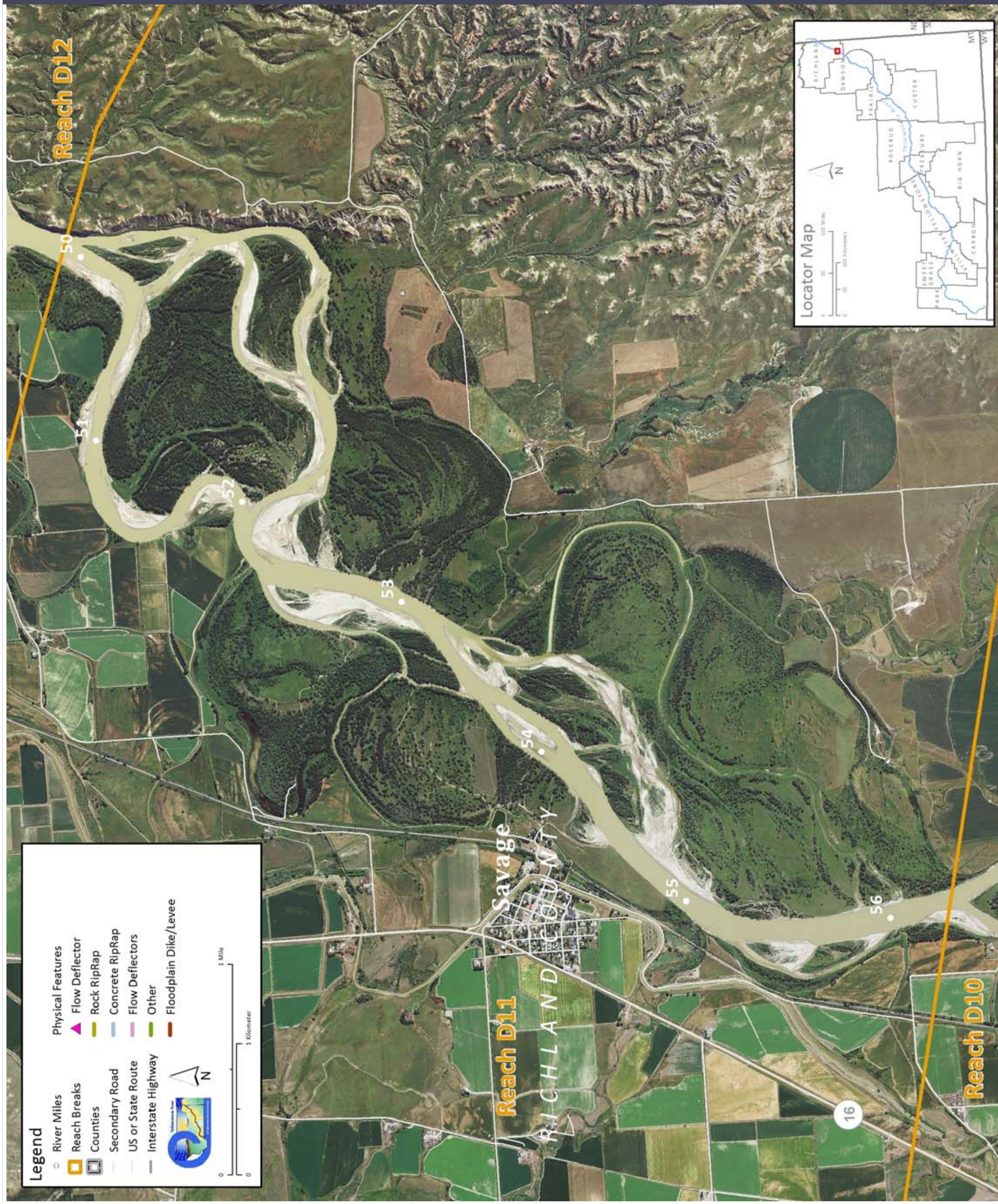
Reach D11 was sampled as part of the avian study. A total of 61 bird species were identified in the reach, indicating high bird species richness. Five bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were found, the Black and white Warbler, Chimney Swift, Dickscissel, Ovenbird, and Plumbeous Vireo. The Red-headed woodpecker was also observed, which has been identified as a Species of Concern (SOC). Reach D11 has seen an increase in the amount of forest area considered at low risk of cowbird parasitism. In 1950, there were 216.4 acres per valley mile of such forest, and by 2001, that number had increased to 247.2 acres per valley mile.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 22 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,370 cfs to 2,220 cfs with human development, a reduction of 50 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,540 cfs under unregulated conditions to 2,750 cfs under regulated conditions, a reduction of 59 percent. Fall and winter low flows are about 3,500 cfs; these discharges are about 60 percent to 80 percent higher than they were prior to development.

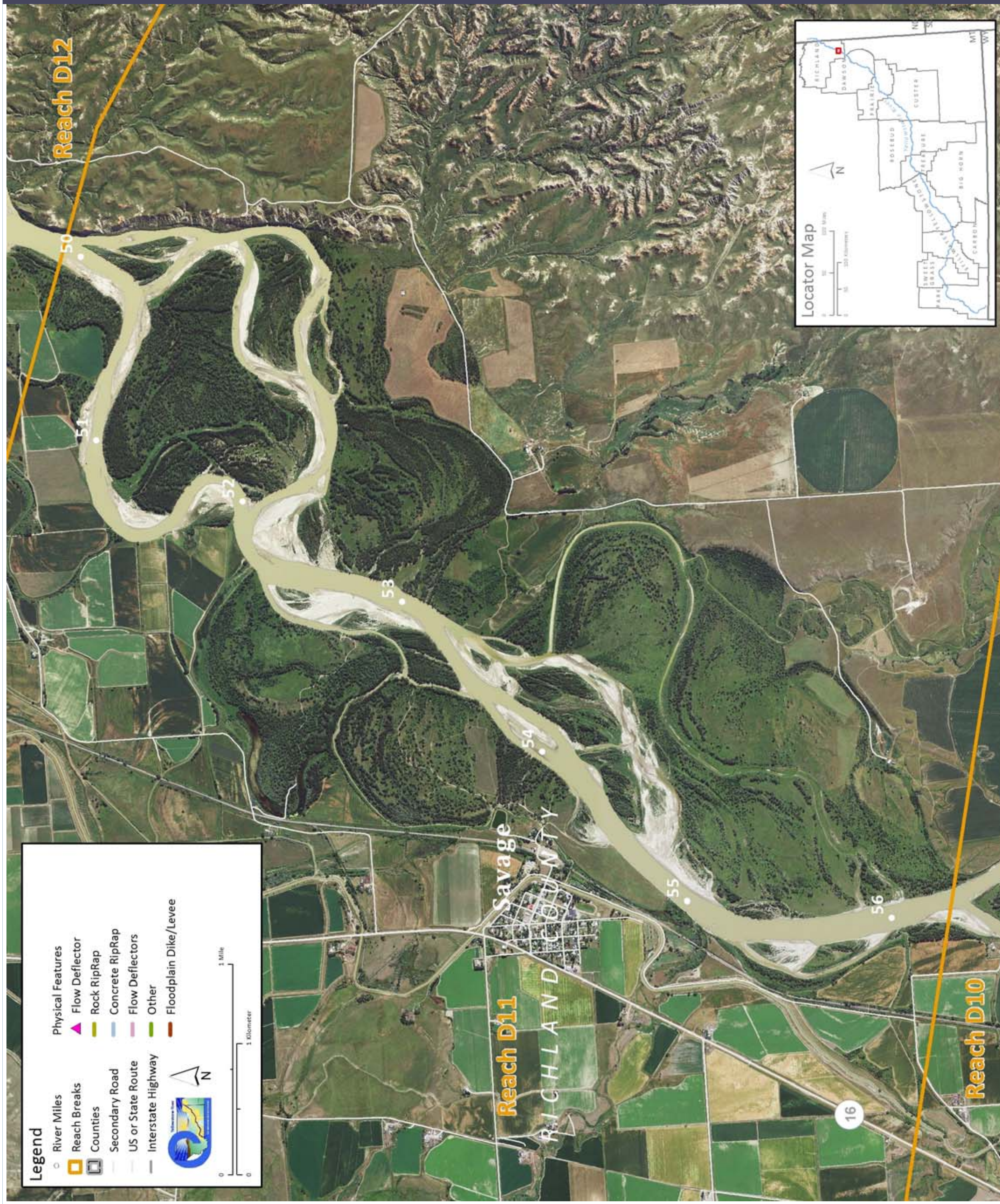
CEA-Related observations in Reach D11 include:
•Reduction in 5-year floodplain footprint with flow alterations
•Increased fall and winter low flows with development
•Reduced summer low flows with development
•Reduced channel forming discharge causing channel contraction
•Extensive riparian encroachment with flow alterations
•Conversion of open sand bars to forested islands

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D11 include:
•Side channel reactivation RM 53L
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	19.1	127.7

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		69,800	90,100	103,000	132,000	144,000	172,000	4,370	6,540
Regulated		54,200	74,800	88,400	118,000	131,000	161,000	2,220	2,750
% Change		-22.35%	-16.98%	-14.17%	-10.61%	-9.03%	-6.40%	-49.20%	-57.95%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	67,400	24,800	7,150
	Regulated	52,000	14,500	5,170
	% Change	**-23%**	**-42%**	**-28%**
Summer	Unregulated	47,600	14,700	6,540
	Regulated	35,300	8,440	2,750
	% Change	**-26%**	**-43%**	**-58%**
Fall	Unregulated	9,900	5,850	1,950
	Regulated	11,300	7,350	3,520
	% Change	**14%**	**26%**	**81%**
Winter	Unregulated	15,900	5,550	2,140
	Regulated	16,400	6,720	3,490
	% Change	**3%**	**21%**	**63%**
Annual	Unregulated	49,800	8,840	2,830
	Regulated	37,000	8,000	3,500
	% Change	**-26%**	**-10%**	**24%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1976	MDT	28-Oct-77	B/W	1:12,000	6329500	5800
1995	USGS DOQQ	8/22/97 - 7/9/96	B/W		6329500	35000
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6329500	4000
2005	NAIP	07/14/2005	color	1-meter pixels	6329500	15900
2007	Woolpert	10/15/2007 - 11/2/0007	Color		6329500	
2009	NAIP	7/11/2009	Color	1-meter pixels	6329500	32600
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/21/2011	Color	1-meter pixels	6329500	46600
2013	NAIP	07/19/2013	color	1-meter pixels	6329500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

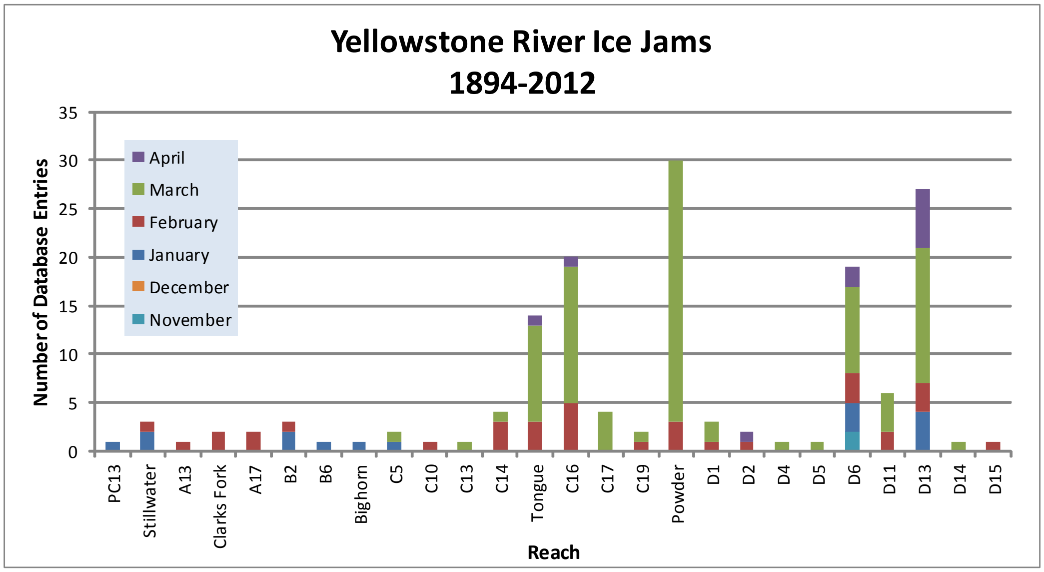
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Other In Channel						
	Bedrock Outcrop	674	1.0%	674	1.0%	0
	Feature Type Totals	**674**	**1.0%**	**674**	**1.0%**	**0**
	Reach Totals	**674**	**1.0%**	**674**	**1.0%**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
3/10/1943	Break-up	54	Severe flooding
3/4/1994	Break-up	54	?
2/13/1996	Break-up	54	Flooding
2/16/1996	Break-up	52	Flooding
3/18/2003	Break-up		?
3/20/2009	Break-up		unknown

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	35,949	72,196	3.01	1950 to 1976:	7.56%
1976	40,583	90,731	3.24	1976 to 1995:	1.55%
1995	34,282	78,367	3.29	1995 to 2001:	-17.69%
2001	33,705	57,459	2.70	1950 to 2001:	-10.09%
Change 1950 - 2001	**-2,244**	**-14,738**	**-0.30**		

Length of Side Channels Blocked

Pre-1950s (ft)	15,601
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	32	0.8%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	72	1.7%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	4135		2524	
Total Floodplain Area (Ac)	4238		3386	
Total Isolated (Ac)	**104**	**2.5%**	**862**	**35.7%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	130	0	0	**130**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
686	1,371	4,334	62	1%	30	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected		RMA Acres	Percent of CMZ
Dike/Levee				
	Railroad		62	1.4%
		Totals	**62**	**1.4%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
256.4	0.0	0.0	0.4	8.5

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	15	15	15	15	0.2%	0.2%	0.2%	0.2%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	25	35	38	35	0.4%	0.5%	0.6%	0.5%
	Totals	**40**	**50**	**52**	**50**	**0.6%**	**0.8%**	**0.8%**	**0.8%**
Agricultural Land									
	Non-Irrigated	2,727	3,334	3,768	3,788	42.4%	51.9%	58.6%	58.9%
	Irrigated	610	584	739	670	9.5%	9.1%	11.5%	10.4%
	Totals	**3,338**	**3,918**	**4,507**	**4,457**	**51.9%**	**61.0%**	**70.1%**	**69.4%**
Channel									
	Channel	3,003	2,392	1,792	1,845	46.7%	37.2%	27.9%	28.7%
	Totals	**3,003**	**2,392**	**1,792**	**1,845**	**46.7%**	**37.2%**	**27.9%**	**28.7%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	2	2	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**2**	**2**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	19	26	27	27	0.3%	0.4%	0.4%	0.4%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	12	12	12	12	0.2%	0.2%	0.2%	0.2%
	Totals	**31**	**37**	**39**	**39**	**0.5%**	**0.6%**	**0.6%**	**0.6%**
Urban									
	Urban Other	0	8	18	18	0.0%	0.1%	0.3%	0.3%
	Urban Residential	13	15	17	17	0.2%	0.2%	0.3%	0.3%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	5	0	0	0.0%	0.1%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**13**	**28**	**35**	**35**	**0.2%**	**0.4%**	**0.5%**	**0.5%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	11	11	0.0%	0.0%	0.2%	0.3%	0.0%	0.2%	0.0%	0.3%
	Flood	610	584	728	658	18.3%	14.9%	16.1%	14.8%	-3.4%	1.2%	-1.4%	-3.5%
	Totals	**610**	**584**	**739**	**670**	**18.3%**	**14.9%**	**16.4%**	**15.0%**	**-3.4%**	**1.5%**	**-1.4%**	**-3.3%**

Non-Irrigated												
Multi-Use	2,328	2,932	3,619	3,641	69.7%	74.8%	80.3%	81.7%	5.1%	5.5%	1.4%	11.9%
Hay/Pasture	400	402	149	147	12.0%	10.3%	3.3%	3.3%	-1.7%	-6.9%	0.0%	-8.7%
Totals	**2,727**	**3,334**	**3,768**	**3,788**	**81.7%**	**85.1%**	**83.6%**	**85.0%**	**3.4%**	**-1.5%**	**1.4%**	**3.3%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.5	0.1	1.0	0.5	1.4	0.3	0.8	1.7	6.7
Max	256.8	208.6	230.0	415.7	493.5	391.8	232.9	18.4	128.6
Average	29.7	22.2	17.9	49.9	88.4	65.9	53.7	8.6	46.2
Sum	1,037.8	756.3	608.7	1,597.1	2,210.6	2,108.3	483.5	25.8	277.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	355.9
Channel to Riparian (acres)	650.8
Riparian Encroachment (acres)	**294.9**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	700.9
1950s Floodplain Mapped as 2011 Channel (Ac)	74.3
Total Recruitment (1950s to 2011)(Ac)	**775.2**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	24.4	119.1	44.7	0.0	**188.2**
Acres/Valley Mile	4.5	22.1	8.3	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	31.79	1.05%	34.72	1.00	9.53	3.42

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	303.0	193.9	10.8%
Secondary Channel	211.9	113.8	6.3%
Secondary Channel (Seasonal)	303.9	233.5	13.0%
Channel Crossover	152.9	112.8	6.3%
Point Bar		56.5	3.2%
Side Bar		76.0	4.2%
Mid-channel Bar		44.4	2.5%
Island	820.7	821.5	45.8%
Dry Channel		139.9	7.8%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern   Potential Species of Concern

Reach	Region	Species
✓	✓	American Robin
✓	✓	American Crow
✓	✓	American Goldfinch
✓	✓	American Kestrel
✓	✓	American Redstart
	✓	Bald Eagle
✓	✓	Baltimore Oriole
		Barn Swallow
✓	✓	Belted Kingfisher
	✓	Black-billed Cuckoo
✓	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
✓	✓	Black-and-white Warbler
✓	✓	Black-headed Grosbeak
✓	✓	Blue Jay
	✓	Bobolink
✓	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
		Brown Creeper
✓	✓	Brown Thrasher
✓	✓	Bullock's Oriole
		Canada Goose
✓	✓	Cedar Waxwing
✓	✓	Chimney Swift
	✓	Chipping Sparrow
✓	✓	Clay-collared Sparrow
		Cliff Swallow
✓	✓	Common Grackle
		Common Merganser
✓	✓	Common Nighthawk
		Common Raven
✓	✓	Common Yellowthroat
	✓	Cooper's Hawk
✓	✓	Dickcissel
✓	✓	Downy Woodpecker
	✓	Eastern Bluebird
✓	✓	Eastern Kingbird
		Eurasian Collared-dove
✓	✓	European Starling
✓	✓	Field Sparrow
✓	✓	Franklin's Gull
✓	✓	Grasshopper Sparrow
✓	✓	Gray Catbird
	✓	Great Blue Heron
✓	✓	Great Horned Owl
✓	✓	Hairy Woodpecker
		House Finch
✓	✓	House Wren
✓	✓	Killdeer
		Lark Bunting
✓	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
✓	✓	Mallard
		Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
	✓	Orchard Oriole
		Osprey
✓	✓	Ovenbird
✓	✓	Plumbeous Vireo
✓	✓	Red-headed Woodpecker
		Red-naped Sapsucker
✓	✓	Red Crossbill
✓	✓	Ring-necked Pheasant
✓	✓	Red-tailed hawk
	✓	Rock Dove
✓	✓	Red-winged Blackbird
✓	✓	Red-eyed Vireo
✓	✓	Red-breasted Grosbeak
		Say's Phoebe
✓	✓	Savannah Sparrow
✓	✓	Song Sparrow
	✓	Spotted Sandpiper
✓	✓	Spotted Towhee
		Sharp-shinned Hawk
		Swainson's Thrush
		Sandhill Crane
✓	✓	Tree Swallow
		Turkey Vulture
		Upland Sandpiper
		Vesper Sparrow
		Violet-green Swallow
✓	✓	Warbling Vireo
✓	✓	Western Kingbird
✓	✓	Western Meadowlark
✓	✓	Western Wood-pewee
✓	✓	White-breasted Nuthatch
		White-throated Swift
	✓	Wild Turkey
✓	✓	Wood Duck
✓	✓	Yellow-bellied Sapsucker
	✓	Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
		Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

County	Richland	**Upstream River Mile**	49.9
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	36.3
General Location	Seven Sisters	**Length**	13.60 mi (21.89 km)
General Comments	Secondary channel on valley wall; Sinuous; long abandoned secondary channel		

Narrative Summary

Reach D12 is located in Richland County at Seven Sisters. The Seven Sisters Fishing Access Site is located in the lower portion of the reach. The reach is a 13.6 mile long Partially Confined Anabranching reach type, indicating some influence of the valley wall along with extensive forested islands. This reach supports over 20 miles of side channels, and islands that are miles long and over ½ mile wide.

There are almost 7,000 feet of bank armor in the reach, and about one third of that was built since 2001. Most of the armor (3,250 feet) is rock riprap, and there are about 2,000 feet each of concrete riprap and flow deflectors. A total of 5 percent of the bank is armored, which is a relatively low concentration of bank armor for the Yellowstone River. All of the armor is protecting agricultural land, most of it against a flood irrigated field on the left bank in the lower end of the reach at RM 37.

Since 1950, a side channel that is almost three miles long was blocked at RM 45.3L. There have also been some gains in side channel length in the reach, such that the net change in length is a loss of approximately one mile. As of 2001, this reach supported almost 21 miles of anabranching channel.

Land use is dominated by agriculture, with 583 acres of pivot irrigation development since 1950. Physical features such as bank armor, dikes, and levees have isolated 3 percent of the Channel Migration Zone in Reach D12, and as of 2011 there were 224 acres of land in the CMZ under pivot irrigation, and 900 acres under flood.

Reach D12 shows, like most other reaches below the Bighorn River, a shrinking channel with reduced rates of erosion and floodplain turnover. For example, the bankfull channel area in the reach dropped by 480 acres since 1950, and there was almost 600 acres of riparian encroachment into old channel areas. Floodplain turnover rates have dropped from 2.1 acres/valley mile/year from 1950-1976 to 1.3 acres/valley mile/year from 1976-2001. This equates to 330 fewer acres of floodplain turnover since 1976. There has also been a net loss of 159 acres of open bar area as the channel has become smaller and more forested. On the floodplain, riparian acreage has decreased; about 350 acres or 9 percent of the total riparian area was cleared for irrigation since 1950.

There are 75 acres of Russian olive in the reach.

The 100-year floodplain has been isolated in this reach, but compared to other reaches the isolation has been fairly minor. About 300 acres of 100-year floodplain has been isolated by human development, which is 5 percent of the total 100-year floodplain. Although only about 5 percent of the 100-year floodplain has been isolated, the impact of flow alterations on the smaller 5-year floodplain has been much more severe; 42 percent of the historic 5-year floodplain is no longer inundated at that frequency. The isolation of the historic 5-year floodplain, which is due primarily to flow alterations, has been associated with increased development in these areas; currently there are about 300 acres of flood irrigated land and within the historic 5-year floodplain footprint.

There is an animal feeding facility on the right bank at RM 46.8.

Reach D12 was sampled as part of the fisheries study. A total of 37 fish species were sampled in the reach. Three species collected in the reach have been identified by the Montana Natural Heritage Program as Species of Concern (SOC): Pallid Sturgeon, Sauger, and Sturgeon Chub.

Reach D12 was also sampled as part of the avian study. A total of 59 bird species were identified in the reach. All five bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) on the Yellowstone River were also found, the Black and White Warbler, the Chimney Swift, the Dickscissel, the Ovenbird, and the Plumbeous Vireo. Similarly, all three bird species identified as Species of Concern (SOC) were identified: the Black-billed Cuckoo, Bobolink, and Red-headed Woodpecker. In contrast to most other reaches, Reach D12 has seen an increase in the forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 103 acres per valley mile of such forest, and that number increased to 115 acres per valley mile by 2001.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 22 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,310 cfs to 2,410 cfs with human development, a reduction of 50 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,470 cfs under unregulated conditions to 2,680 cfs under regulated conditions, a reduction of 59 percent.

CEA-Related observations in Reach D12 include:
•Increase in area at low risk of cowbird parasitism with riparian encroachment

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D12 include:
•Nutrient management at animal handling facility at RM 46.8R
•Side channel reactivation at RM 45.3R
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	5.5	134.1

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		69,800	90,300	103,000	132,000	144,000	172,000	4,310	6,470
Regulated		54,300	74,900	88,600	119,000	132,000	163,000	2,140	2,680
% Change		-22.21%	-17.05%	-13.98%	-9.85%	-8.33%	-5.23%	-50.35%	-58.58%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Season		5%	50%	95%
Spring	Unregulated	67,400	24,700	7,180
	Regulated	52,000	14,400	5,190
	% Change	**-23%**	**-42%**	**-28%**
Summer	Unregulated	47,700	14,700	6,470
	Regulated	35,300	8,370	2,680
	% Change	**-26%**	**-43%**	**-59%**
Fall	Unregulated	9,910	5,830	1,940
	Regulated	11,300	7,330	3,510
	% Change	**14%**	**26%**	**81%**
Winter	Unregulated	16,100	5,580	2,140
	Regulated	16,600	6,750	3,490
	% Change	**3%**	**21%**	**63%**
Annual	Unregulated	49,700	8,830	2,830
	Regulated	37,000	8,000	3,480
	% Change	**-26%**	**-9%**	**23%**

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1957	USDA	???	B/W	1:20,000	6329500	
1976	MDT	28-Oct-77	B/W	1:12,000	6329500	5800
1995	USGS DOQQ	8/3/97 - 8/22/97	B/W		6329500	23000
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6329500	4000
2005	NAIP	07/14/2005	color	1-meter pixels	6329500	15900
2007	Woolpert	10/15/2007 - 11/2/0007	Color		6329500	
2009	NAIP	7/11/2009	Color	1-meter pixels	6329500	32600
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/21/2011	Color	1-meter pixels	6329500	46600
2011	NAIP	7/15/2011	Color	1-meter pixels	6329500	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6329500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Tree Revetments	531	0.4%	404	0.3%	-127
	Rock RipRap	595	0.4%	3,251	2.3%	2,656
	Flow Deflectors	356	0.2%	474	0.3%	118
	Concrete RipRap	1,945	1.4%	1,945	1.4%	0
	Between Flow Deflectors	1,328	0.9%	1,328	0.9%	0
	Feature Type Totals	**4,755**	**3.3%**	**7,402**	**5.2%**	**2,647**
Floodplain Control						
	Floodplain Dike/Levee	350	0.2%	350	0.2%	0
	Feature Type Totals	**350**	**0.2%**	**350**	**0.2%**	**0**
	Reach Totals	**5,106**	**3.6%**	**7,752**	**5.4%**	**2,647**

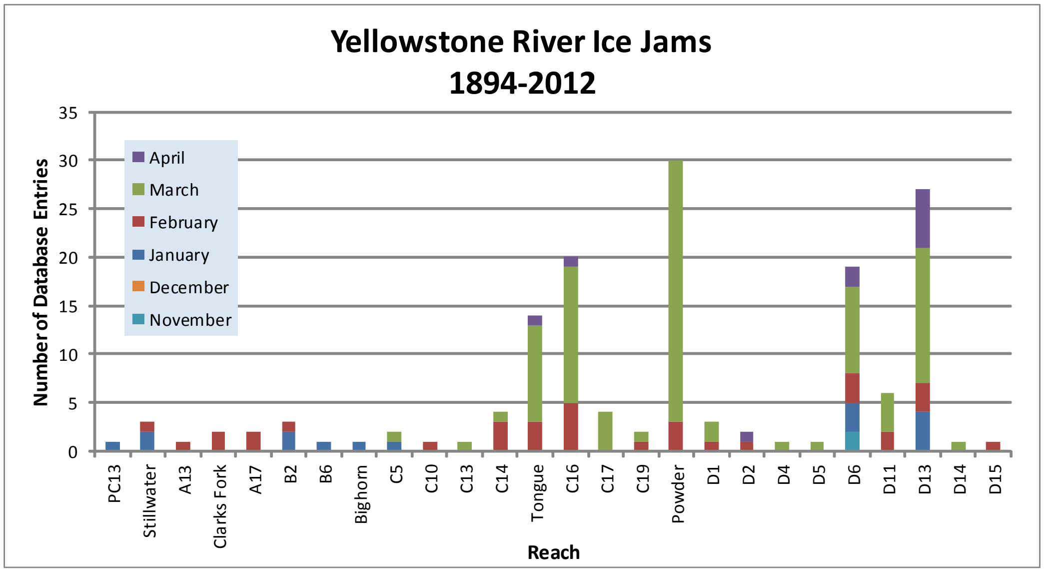
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	1,289	0	656	0	0	0	0	0
Flow Deflectors/Between FDs	1,683	0	0	0	0	0	0	0
Rock RipRap	0	423	171	0	0	0	0	0
Tree Revetments	531	0	0	0	0	0	0	0
Totals	**3,503**	**423**	**827**	**0**	**0**	**0**	**0**	**0**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	75,467	116,193	2.54
1976	72,988	107,995	2.48
1995	70,922	121,394	2.71
2001	71,860	110,374	2.54
Change 1950 - 2001	**-3,607**	**-5,818**	**0.00**

	% Change in Braiding
1950 to 1976:	-2.36%
1976 to 1995:	9.36%
1995 to 2001:	-6.48%
1950 to 2001:	-0.15%

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	14,624

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	11	0.2%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	285	3.9%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	49	0.7%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	6965		4622	
Total Floodplain Area (Ac)	7310		6736	
Total Isolated (Ac)	**345**	**4.7%**	**2113**	**42.4%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	300	0	27	**328**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
556	1,113	7,034	126	2%	639	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Non-Irrigated	46	0.6%
	Irrigated	23	0.3%
Flow Deflectors			
	Irrigated	122	1.6%
Dike/Levee			
	Railroad	7	0.1%
	Totals	**198**	**2.6%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
896.1	0.0	244.1	4.1	6.4

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	60	109	166	155	0.6%	1.0%	1.6%	1.5%
	Totals	**60**	**109**	**166**	**155**	**0.6%**	**1.0%**	**1.6%**	**1.5%**
Agricultural Land									
	Non-Irrigated	3,778	3,965	3,128	3,139	36.2%	38.0%	29.9%	30.0%
	Irrigated	2,108	2,241	3,003	2,947	20.2%	21.4%	28.7%	28.2%
	Totals	**5,886**	**6,206**	**6,131**	**6,087**	**56.3%**	**59.4%**	**58.7%**	**58.3%**
Channel									
	Channel	4,458	4,074	4,091	4,146	42.7%	39.0%	39.2%	39.7%
	Totals	**4,458**	**4,074**	**4,091**	**4,146**	**42.7%**	**39.0%**	**39.2%**	**39.7%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	2	2	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**2**	**2**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	26	42	41	41	0.3%	0.4%	0.4%	0.4%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	17	17	17	17	0.2%	0.2%	0.2%	0.2%
	Totals	**44**	**59**	**59**	**59**	**0.4%**	**0.6%**	**0.6%**	**0.6%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irr													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	360	583	0.0%	0.0%	5.9%	9.6%	0.0%	5.9%	3.7%	9.6%
	Flood	2,108	2,241	2,643	2,365	35.8%	36.1%	43.1%	38.9%	0.3%	7.0%	-4.3%	3.0%
	Totals	**2,108**	**2,241**	**3,003**	**2,947**	**35.8%**	**36.1%**	**49.0%**	**48.4%**	**0.3%**	**12.9%**	**-0.6%**	**12.6%**

NoIrr

Multi-Use	3,111	3,170	2,961	2,986	52.8%	51.1%	48.3%	49.1%	-1.8%	-2.8%	0.8%	-3.8%
Hay/Pasture	668	795	167	154	11.3%	12.8%	2.7%	2.5%	1.5%	-10.1%	-0.2%	-8.8%
Totals	**3,778**	**3,965**	**3,128**	**3,139**	**64.2%**	**63.9%**	**51.0%**	**51.6%**	**-0.3%**	**-12.9%**	**0.6%**	**-12.6%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.5	0.2	0.8	3.1	0.6	0.2	4.0	4.4	4.2
Max	247.0	140.2	87.4	235.5	658.4	804.3	78.4	137.8	189.5
Average	21.5	14.0	11.3	64.5	81.6	71.8	27.1	71.1	33.8
Sum	1,611.4	870.4	473.5	2,128.4	2,856.4	3,517.4	379.5	284.3	337.7

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	518.6
Channel to Riparian (acres)	1115.6
Riparian Encroachment (acres)	**597.0**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	1123.2
1950s Floodplain Mapped as 2011 Channel (Ac)	578.0
Total Recruitment (1950s to 2011)(Ac)	**1701.2**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	28.0	117.2	139.8	0.0	**285.0**
Acres/Valley Mile	2.6	10.9	13.0	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	74.77	1.37%	82.86	0.12	25.02	13.06

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
✓	✓	Bigmouth buffalo
✓	✓	Black bullhead
✓	✓	Black crappie
	✓	Blue sucker
✓	✓	Bluegill
✓	✓	Brook stickleback
		Brown trout
✓	✓	Burbot
	✓	Catfish species
✓	✓	Channel catfish
✓	✓	Common carp
✓	✓	Creek chub
✓	✓	Emerald shiner
✓	✓	Fathead minnow
✓	✓	Flathead chub
✓	✓	Freshwater drum
✓	✓	Goldeye
✓	✓	Green sunfish
	✓	Lake chub
		Largemouth bass
✓	✓	Longnose dace
✓	✓	Longnose sucker
✓	✓	Minnow species
		Mottled sculpin
		Mountain sucker
		Mountain whitefish
✓	✓	Northern pike
✓	✓	Northern plains killifish
✓	✓	Northern redbelly dace
✓	✓	Pallid sturgeon
	✓	Pumpkinseed
		Rainbow trout
✓	✓	River carpsucker
		Rock bass
✓	✓	Sand shiner
✓	✓	Sauger
✓	✓	Shorthead redhorse
	✓	Shortnose gar
✓	✓	Shovelnose sturgeon
	✓	Sicklefin chub
	✓	Smallmouth bass
✓	✓	Smallmouth buffalo
✓	✓	Stonecat
✓	✓	Sturgeon chub
✓	✓	Sucker species
✓	✓	Sunfish species
✓	✓	Walleye
✓	✓	Western silvery minnow
✓	✓	White bass
✓	✓	White crappie
✓	✓	White sucker
		Yellow bullhead
		Yellow perch

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	608.4	334.5	8.2%
Rip Rap Bottom	23.1	16.6	0.4%
Rip Rap Margin	24.4	21.9	0.5%
Bluff Pool	16.3	16.9	0.4%
Terrace Pool	40.1	30.7	0.8%
Secondary Channel	122.7	110.7	2.7%
Secondary Channel (Seasonal)	479.7	402.0	9.8%
Channel Crossover	439.8	269.4	6.6%
Point Bar		247.3	6.0%
Side Bar		107.7	2.6%
Mid-channel Bar		69.6	1.7%
Island	2,336.7	2,336.7	57.1%
Dry Channel		127.5	3.1%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern   Potential Species of Concern

Reach	Region	Species
✓	✓	American Robin
✓	✓	American Crow
✓	✓	American Goldfinch
✓	✓	American Kestrel
✓	✓	American Redstart
✓	✓	Bald Eagle
✓	✓	Baltimore Oriole
		Barn Swallow
	✓	Belted Kingfisher
✓	✓	Black-billed Cuckoo
✓	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
✓	✓	Black-and-white Warbler
✓	✓	Black-headed Grosbeak
✓	✓	Blue Jay
✓	✓	Bobolink
✓	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
		Brown Creeper
✓	✓	Brown Thrasher
✓	✓	Bullock's Oriole
		Canada Goose
✓	✓	Cedar Waxwing
✓	✓	Chimney Swift
✓	✓	Chipping Sparrow
✓	✓	Clay-collared Sparrow
		Cliff Swallow
✓	✓	Common Grackle
		Common Merganser
	✓	Common Nighthawk
		Common Raven
✓	✓	Common Yellowthroat
	✓	Cooper's Hawk
✓	✓	Dickcissel
✓	✓	Downy Woodpecker
	✓	Eastern Bluebird
✓	✓	Eastern Kingbird
		Eurasian Collared-dove
✓	✓	European Starling
✓	✓	Field Sparrow
✓	✓	Franklin's Gull
✓	✓	Grasshopper Sparrow
✓	✓	Gray Catbird
✓	✓	Great Blue Heron
	✓	Great Horned Owl
✓	✓	Hairy Woodpecker
		House Finch
✓	✓	House Wren
	✓	Killdeer
		Lark Bunting
✓	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
	✓	Mallard
		Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
✓	✓	Orchard Oriole
		Osprey
✓	✓	Ovenbird
✓	✓	Plumbeous Vireo
✓	✓	Red-headed Woodpecker
		Red-naped Sapsucker
	✓	Red Crossbill
✓	✓	Ring-necked Pheasant
✓	✓	Red-tailed hawk
	✓	Rock Dove
✓	✓	Red-winged Blackbird
✓	✓	Red-eyed Vireo
	✓	Red-breasted Grosbeak
		Say's Phoebe
✓	✓	Savannah Sparrow
✓	✓	Song Sparrow
✓	✓	Spotted Sandpiper
✓	✓	Spotted Towhee
		Sharp-shinned Hawk
		Swainson's Thrush
		Sandhill Crane
✓	✓	Tree Swallow
		Turkey Vulture
		Upland Sandpiper
		Vesper Sparrow
		Violet-green Swallow
✓	✓	Warbling Vireo
	✓	Western Kingbird
✓	✓	Western Meadowlark
✓	✓	Western Wood-pewee
✓	✓	White-breasted Nuthatch
		White-throated Swift
	✓	Wild Turkey
	✓	Wood Duck
	✓	Yellow-bellied Sapsucker
	✓	Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
		Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.

There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

County	Richland	**Upstream River Mile**	36.3
Classification	PCM/I: Partly confined meandering/islands	**Downstream River Mile**	27.8
General Location	To Sidney	**Length**	8.50 mi (13.68 km)

General Comments

Narrative Summary

Reach D13 is located just upstream of Sidney. It is 8.5 miles long, and is a PCM/I reach type, indicating a primary meandering channel thread with distinct islands largely formed by historic bendway cutoffs. The reach has multiple pipeline crossings, and the Highway 23 Bridge and approach have confined the river and isolated floodplain area. Floodplain development for irrigated agricultural is extensive, and in many cases irrigated fields intersect the channel bank. These locations are commonly armored, and low field dikes affect floodplain access.

In 2011 there was almost 16,000 feet of bank armor in the reach, protecting 16 percent of the total bank line. That includes 2,440 feet of car bodies. The car body revetments are all located off of the main channel at RM 32.2L. About ½ mile of rock riprap was constructed between 2001 and 2011.

Although no side channels have been intentionally blocked in the reach, there has still been a net loss of almost two miles of side channel since 1950, reflecting passive abandonment of side channels with flow alterations.

There are three mapped pipeline crossings in the reach, two at the Sidney Bridge and another about a mile upstream. The two on the bridge are apparently installed on the bridge structure itself. The one upstream at RM 32.1 is described as an LPG pipeline installed in 1997; however no more information was available.

Reach D13 has had 28 reported ice jam events since 1917. Especially severe damages were reported in the ice jam of March 25, 1943.

Human development has resulted in isolation of 18 percent of the historic 100-year floodplain and 26 percent of the 5-year floodplain. This isolation includes the effects of transportation infrastructure embankments (mainly Highway 23), low agricultural dikes on the edges of irrigated fields, and reduced flood magnitudes. There has been fairly extensive land use encroachment into the Channel Migration Zone: as of 2011 there were 250 acres of pivot irrigation and 137 acres of urban/exurban land uses within the CMZ, making these areas especially prone to the threat of river erosion. One drill pad was mapped within 1,500 feet of the river at RM 32. There is also a large animal handling facility that drains to an irrigation return flow point at RM 29.

Reach D13 shows, like most other reaches below the Bighorn River, a shrinking channel with reduced rates of erosion and floodplain turnover. The bankfull channel area in the reach dropped by 220 acres since 1950, and there was a similar amount of mapped riparian encroachment into old channel areas. Floodplain turnover rates have dropped from 14.3 acres per year from 1950-1976 to 6.1 acres per year from 1976-2001. There has also been a net loss of 45 acres of open bar area as the channel has become smaller and more forested. On the floodplain, riparian acreage has decreased; about 424 acres or 27 percent of the total riparian area was cleared for irrigation since 1950.

Like numerous reaches below the Bighorn River confluence, Reach D13 exhibits a shift from a largely braided pattern in 1950 to an anabranching pattern today. The pattern shift reflects the fact that side channels that used to flow around open bars (braided) now flow around wooded islands (anabranching). This shift appears largely due to riparian encroachment onto sand bars since 1950. This encroachment reflects the flow alterations identified in the reach, and may also be due to the altered sediment regime imposed by upstream influences including Yellowtail Dam. Changes in sediment loading have not been quantified in the CEA.

There are 45 acres of Russian olive mapped in the reach.

Reach D13 was sampled as part of the fisheries study. A total of 38 fish species were sampled in the reach, including six Species of Concern: the Blue Sucker, Pallid Sturgeon, Sauger, Shortnose Gar, Sicklefin Chub, and Sturgeon Chub.

Reach D13 was also sampled as part of the avian study. A total of 39 bird species were identified in the reach. The Red-headed Woodpecker was found, which is a Species of Concern (SOC). In contrast to most other reaches, Reach D12 has seen a reduction in the forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 27.6 acres per valley mile of such forest, and that number decreased to 18.1 acres per valley mile by 2001.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The magnitude of the 100-year flood is now 134,000 cfs, which 6 percent lower than it was pre-development (143,000 cfs). The 2-year flood, which strongly influences overall channel form, has dropped by 22 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,190 cfs to 2,000 cfs with human development, a reduction of 52 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,340 cfs under unregulated conditions to 2,550 cfs under regulated conditions, a reduction of 60 percent.

Seasonal low flows have increased by 82 percent in the fall and 63 percent in the winter. Both fall and winter base flows are currently about 3,500 cfs.

CEA-Related observations in Reach D13 include:
•Conversion of river pattern from braided to anabranching due to riparian encroachment onto sand bars since 1950.
•Passive side channel abandonment due to hydrologic alterations and potentially downcutting due to CMZ confinement.
•100-year floodplain isolation due to low agricultural field dikes.
•100-year floodplain isolation due to transportation infrastructure.
•Channel Migration Zone (CMZ) restrictions that significantly confine the river corridor, potentially causing downcutting. This may be an important Increase in area at low risk of cowbird parasitism with riparian encroachment

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D13 include:
•Nutrient Management at Animal Handling Facility at RM 29L
•Pipeline Crossing PRACTICE RM 32.1
•Old car body removal RM 32.2L
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No		6329500
Location	#Error	Sidney
Period of Record	#Error	1911-2015
Distance To (miles)	#Error	-5.5

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		69,900	90,500	104,000	132,000	143,000	170,000	4,190	6,340
Regulated		54,300	75,100	89,100	120,000	134,000	166,000	2,000	2,550
% Change		-22.32%	-17.02%	-14.33%	-9.09%	-6.29%	-2.35%	-52.27%	-59.78%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	67,400	24,600	7,250
	Regulated	52,000	14,300	5,220
	% Change	**-23%**	**-42%**	**-28%**
Summer	Unregulated	47,800	14,600	6,340
	Regulated	35,300	8,230	2,550
	% Change	**-26%**	**-44%**	**-60%**
Fall	Unregulated	9,950	5,800	1,920
	Regulated	11,300	7,300	3,490
	% Change	**14%**	**26%**	**82%**
Winter	Unregulated	16,500	5,640	2,150
	Regulated	17,000	6,810	3,510
	% Change	**3%**	**21%**	**63%**
Annual	Unregulated	49,700	8,810	2,830
	Regulated	36,900	7,990	3,440
	% Change	**-26%**	**-9%**	**22%**

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1976	MDT	28-Oct-77	B/W	1:12,000	6329500	5800
1995	USGS DOQQ	7/28/95 - 8/3/97	B/W		6329500	23000
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6329500	4000
2005	NAIP	07/14/2005	color	1-meter pixels	6329500	15900
2007	Woolpert	10/15/2007 - 11/2/0007	Color		6329500	
2009	NAIP	7/11/2009	Color	1-meter pixels	6329500	32600
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/15/2011	Color	1-meter pixels	6329500	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6329500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Tire Revetment	520	0.6%	0	0.0%	-520
	Rock RipRap	3,976	4.4%	6,387	7.1%	2,410
	Flow Deflectors	962	1.1%	944	1.0%	-18
	Concrete RipRap	3,329	3.7%	3,329	3.7%	0
	Car Bodies	2,437	2.7%	2,437	2.7%	0
	Between Flow Deflectors	3,074	3.4%	3,235	3.6%	161
	Feature Type Totals	**14,298**	**15.8%**	**16,332**	**18.1%**	**2,033**
	Reach Totals	**14,298**	**15.8%**	**16,332**	**18.1%**	**2,033**

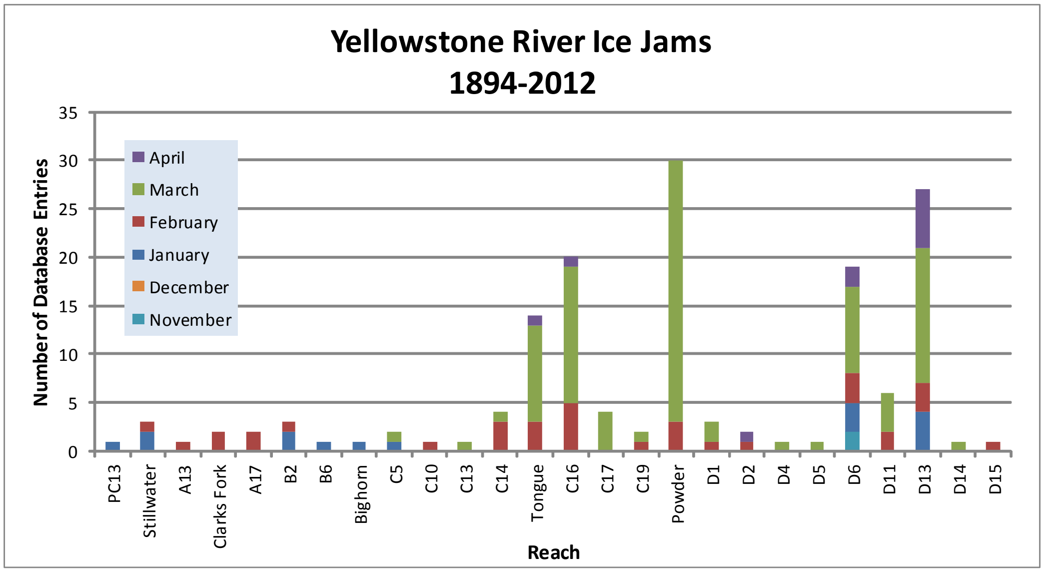
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Car Bodies	2,263	0	0	0	0	0	0	174
Concrete RipRap	2,522	0	0	0	0	0	0	807
Flow Deflectors/Between FDs	1,496	2,394	0	0	0	0	0	0
Rock RipRap	748	0	984	66	0	0	0	2,178
Tire Revetment	518	0	0	0	0	0	0	0
Totals	**7,547**	**2,394**	**984**	**66**	**0**	**0**	**0**	**3,159**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
	NA	31	35K USD estimated rural damages
4/3/1917	NA	31	?
3/31/1923	NA	31	?
1/1/1927	NA	31	21,400 USD estimated rural damages
3/2/1938	NA	31	?
3/22/1939	NA	31	?
3/25/1943	NA	31	484,800 USD estimated rural damages
1/1/1944	NA	31	86,600 USD estimated rural damages
1/1/1946	NA	31	50,400 USD estimated rural damages
1/1/1948	NA	31	11,300 USD estimated rural damages
3/8/1949	NA	31	50,500 USD estimated rural damages
4/4/1950	NA	31	?
3/27/1951	NA	31	Severe flooding, evacuations, 100,000s USD in damages
4/1/1952	Freeze-up	31	44,900 USD estimated rural damages,severe flooding
4/3/1955	NA	31	1,800 USD estimated rural damages
3/26/1956	NA	31	?
3/21/1959	NA	31	30K USD estimated rural damages
3/21/1960	NA	31	69K USD estimated rural damages
3/17/1961	NA	31	?
4/7/1965	NA	31	?
4/7/1965	NA	31	?
3/26/1969	Break-up	31	230K USD and 14,000 acres flooded
3/19/1979	NA	31	?
2/27/1986	NA	31	?
3/6/1994	NA	31	?
2/13/1996	Break-up	31	High water
2/14/1997	NA	31	?
3/19/2011	Break-up		

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	44,020	49,325	2.12	1950 to 1976:	-1.37%
1976	43,740	47,743	2.09	1976 to 1995:	1.60%
1995	44,321	49,858	2.12	1995 to 2001:	-12.40%
2001	45,127	38,872	1.86	1950 to 2001:	-12.22%
Change 1950 - 2001	**1,106**	**-10,453**	**-0.26**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	31	0.7%		
Agriculture (generally relates to field boundaries)	552	13.1%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	38	0.9%		
Levee/Riprap (protecting urban, industrial, etc.)	16	0.4%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	129	3.1%		
Total Not Isolated (Ac)	3434		2297	
Total Floodplain Area (Ac)	4200		2764	
Total Isolated (Ac)	**766**	**18.2%**	**467**	**25.6%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	163	0	19	**183**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
521	1,042	3,541	598	17%	0	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	177	5.0%
RipRap/Flow Deflectors			
	Irrigated	233	6.6%
RipRap			
	Irrigated	128	3.6%
Flow Deflectors			
	Irrigated	101	2.9%
	Totals	**639**	**18.1%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
585.1	0.0	250.7	136.9	9.9

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	73	163	209	210	1.1%	2.4%	3.0%	3.1%
	Totals	**73**	**163**	**209**	**210**	**1.1%**	**2.4%**	**3.0%**	**3.1%**
Agricultural Land									
	Non-Irrigated	1,843	1,799	1,831	1,780	26.8%	26.2%	26.6%	25.9%
	Irrigated	3,210	3,141	3,230	3,218	46.7%	45.7%	46.9%	46.8%
	Totals	**5,052**	**4,940**	**5,061**	**4,998**	**73.4%**	**71.8%**	**73.6%**	**72.7%**
Channel									
	Channel	1,695	1,543	1,343	1,398	24.6%	22.4%	19.5%	20.3%
	Totals	**1,695**	**1,543**	**1,343**	**1,398**	**24.6%**	**22.4%**	**19.5%**	**20.3%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	158	185	192	0.0%	2.3%	2.7%	2.8%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	5	19	24	24	0.1%	0.3%	0.4%	0.4%
	Totals	**5**	**176**	**209**	**216**	**0.1%**	**2.6%**	**3.0%**	**3.1%**
Transportation									
	Public Road	44	47	47	47	0.6%	0.7%	0.7%	0.7%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	9	9	9	9	0.1%	0.1%	0.1%	0.1%
	Totals	**53**	**57**	**57**	**57**	**0.8%**	**0.8%**	**0.8%**	**0.8%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irr													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	316	894	0.0%	0.0%	6.3%	17.9%	0.0%	6.3%	11.6%	17.9%
	Flood	3,210	3,141	2,913	2,324	63.5%	63.6%	57.6%	46.5%	0.0%	-6.0%	-11.0%	-17.0%
	Totals	**3,210**	**3,141**	**3,230**	**3,218**	**63.5%**	**63.6%**	**63.8%**	**64.4%**	**0.1%**	**0.2%**	**0.6%**	**0.9%**

NoIrr

Multi-Use	1,549	1,546	1,731	1,747	30.7%	31.3%	34.2%	35.0%	0.6%	2.9%	0.7%	4.3%
Hay/Pasture	293	253	100	33	5.8%	5.1%	2.0%	0.7%	-0.7%	-3.2%	-1.3%	-5.1%
Totals	**1,843**	**1,799**	**1,831**	**1,780**	**36.5%**	**36.4%**	**36.2%**	**35.6%**	**-0.1%**	**-0.2%**	**-0.6%**	**-0.9%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.5	0.2	0.7	2.2	0.3	2.0	3.7	5.3	8.8
Max	175.6	31.2	43.2	110.3	279.9	346.3	51.5	31.8	19.4
Average	26.7	6.6	11.6	32.0	31.7	41.1	22.9	16.8	14.1
Sum	987.8	277.2	372.7	641.0	1,014.0	1,273.4	114.5	67.4	28.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	231.2
Channel to Riparian (acres)	522.9
Riparian Encroachment (acres)	**291.7**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	546.4
1950s Floodplain Mapped as 2011 Channel (Ac)	104.1
Total Recruitment (1950s to 2011)(Ac)	**650.5**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	65.0	126.5	60.6	0.0	**252.0**
Acres/Valley Mile	8.5	16.6	7.9	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	44.74	3.16%	145.58	2.81	22.19	6.15

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region	Species
☑	☑	Bigmouth buffalo
☑	☑	Black bullhead
☑	☑	Black crappie
☑	☑	Blue sucker
☑	☑	Bluegill
☑	☑	Brook stickleback
☐	☐	Brown trout
☑	☑	Burbot
☐	☑	Catfish species
☑	☑	Channel catfish
☑	☑	Common carp
☑	☑	Creek chub
☑	☑	Emerald shiner
☑	☑	Fathead minnow
☑	☑	Flathead chub
☑	☑	Freshwater drum
☑	☑	Goldeye
☑	☑	Green sunfish
☑	☑	Lake chub
☐	☐	Largemouth bass
☑	☑	Longnose dace
☐	☑	Longnose sucker
☑	☑	Minnow species
☐	☐	Mottled sculpin
☐	☐	Mountain sucker
☐	☐	Mountain whitefish
☑	☑	Northern pike
☑	☑	Northern plains killifish
☐	☑	Northern redbelly dace
☑	☑	Pallid sturgeon
☐	☑	Pumpkinseed
☐	☐	Rainbow trout
☑	☑	River carpsucker
☐	☐	Rock bass
☑	☑	Sand shiner
☑	☑	Sauger
☑	☑	Shorthead redhorse
☑	☑	Shortnose gar
☑	☑	Shovelnose sturgeon
☑	☑	Sicklefin chub
☐	☑	Smallmouth bass
☐	☑	Smallmouth buffalo
☑	☑	Stonecat
☑	☑	Sturgeon chub
☑	☑	Sucker species
☑	☑	Sunfish species
☑	☑	Walleye
☑	☑	Western silvery minnow
☑	☑	White bass
☑	☑	White crappie
☑	☑	White sucker
☐	☐	Yellow bullhead
☐	☐	Yellow perch

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	256.0	134.5	10.0%
Rip Rap Bottom	262.2	125.6	9.4%
Rip Rap Margin	25.8	18.2	1.4%
Secondary Channel (Seasonal)	222.7	209.0	15.6%
Channel Crossover	176.1	163.4	12.2%
Point Bar		88.1	6.6%
Side Bar		27.8	2.1%
Mid-channel Bar		37.7	2.8%
Island	400.6	401.2	29.9%
Dry Channel		137.9	10.3%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern **Potential Species of Concern**

Reach	Region	Species
✓	✓	American Robin
	✓	American Crow
✓	✓	American Goldfinch
✓	✓	American Kestrel
✓	✓	American Redstart
✓	✓	Bald Eagle
		Baltimore Oriole
		Barn Swallow
	✓	Belted Kingfisher
	✓	Black-billed Cuckoo
✓	✓	Black-billed Magpie
✓	✓	Black-capped Chickadee
	✓	Black-and-white Warbler
✓	✓	Black-headed Grosbeak
	✓	Blue Jay
	✓	Bobolink
	✓	Brewer's Blackbird
✓	✓	Brown-headed Cowbird
		Brown Creeper
	✓	Brown Thrasher
	✓	Bullock's Oriole
		Canada Goose
✓	✓	Cedar Waxwing
	✓	Chimney Swift
	✓	Chipping Sparrow
	✓	Clay-collared Sparrow
		Cliff Swallow
✓	✓	Common Grackle
		Common Merganser
	✓	Common Nighthawk
		Common Raven
✓	✓	Common Yellowthroat
	✓	Cooper's Hawk
	✓	Dickcissel
✓	✓	Downy Woodpecker
✓	✓	Eastern Bluebird
✓	✓	Eastern Kingbird
		Eurasian Collared-dove
	✓	European Starling
✓	✓	Field Sparrow
	✓	Franklin's Gull
	✓	Grasshopper Sparrow
✓	✓	Gray Catbird
✓	✓	Great Blue Heron
	✓	Great Horned Owl
	✓	Hairy Woodpecker
		House Finch
✓	✓	House Wren
✓	✓	Killdeer
		Lark Bunting
✓	✓	Lark Sparrow
✓	✓	Lazuli Bunting
✓	✓	Least Flycatcher
✓	✓	Mallard
		Mountain Bluebird
✓	✓	Mourning Dove
✓	✓	Northern Flicker
	✓	Orchard Oriole
		Osprey
	✓	Ovenbird
	✓	Plumbeous Vireo
✓	✓	Red-headed Woodpecker
		Red-naped Sapsucker
	✓	Red Crossbill
✓	✓	Ring-necked Pheasant
	✓	Red-tailed hawk
✓	✓	Rock Dove
	✓	Red-winged Blackbird
✓	✓	Red-eyed Vireo
	✓	Red-breasted Grosbeak
		Say's Phoebe
	✓	Savannah Sparrow
✓	✓	Song Sparrow
	✓	Spotted Sandpiper
✓	✓	Spotted Towhee
		Sharp-shinned Hawk
		Swainson's Thrush
		Sandhill Crane
✓	✓	Tree Swallow
		Turkey Vulture
		Upland Sandpiper
		Vesper Sparrow
		Violet-green Swallow
✓	✓	Warbling Vireo
	✓	Western Kingbird
✓	✓	Western Meadowlark
✓	✓	Western Wood-pewee
✓	✓	White-breasted Nuthatch
		White-throated Swift
	✓	Wild Turkey
	✓	Wood Duck
	✓	Yellow-bellied Sapsucker
	✓	Yellow-billed Cuckoo
✓	✓	Yellow-breasted Chat
		Yellow-headed Blackbird
✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

Yellowstone River Reach Narratives

Reach D14

County	Richland	**Upstream River Mile**	27.8
Classification	PCM/I: Partly confined meandering/islands	**Downstream River Mile**	13.5
General Location	To Fariview	**Length**	14.30 mi (23.01 km)
General Comments	Into Mckenzie County, North Dakota: High sinuosity		

Narrative Summary

Reach D14 is located upstream of Fairview. The reach is a 14.3 mile long Partially Confined Meandering with Islands (PCM/I), indicating some valley wall influence, and a meandering main thread with cutoff channels through meander cores forming persistent forested islands.

There is just over a mile of bank armor in the reach, including 3,900 feet of rock riprap and 2,500 feet of flow deflectors. Most of the rock riprap was constructed between 2001 and 2011 (2,300 feet).

Prior to 1950, 3,600 feet of side channel was blocked in the reach at RM 23L.

Similar to many reaches in the Lower Yellowstone Valley, the river channel in Reach D14 has gotten smaller since 1950. The channel contracted by about 309 acres in this reach since 1950, and about 460 acres of riparian vegetation has encroached into old channel areas. This pattern has been consistent in the lower river, and relates primarily to a reduction in flows due to human development. Floodplain turnover rates have dropped from 14.4 acres per year pre-1976 to 6.1 acres per year post-1976. There has also been a major loss of open bar habitat area in the channel; between 1950 and 2001, there was a loss of 510 acres of mid-channel bar area, which can be important habitat to certain species such as least tern.

Land use is predominantly agricultural, with just over a thousand acres of pivot irrigation development since 1950. Development in the reach included conversion of 1,063 acres of 1950s riparian area to other land uses (mostly irrigated agriculture); that represented 36 percent of the entire 1950s riparian footprint. There are 93 acres of pivot irrigated land and 113 acres of urban/exurban development within the Channel Migration Zone (CMZ), making these areas especially susceptible to river erosion. At RM 26L there are three drill pads within the CMZ.

Several dump sites have been mapped on the banks: RM 25R, RM 24.3L, RM 17L, RM 15.8L, and RM 15.8R.

There is one pipeline crossing in Reach D14 at RM 27. It is an 8-inch crude oil pipeline that has been Horizontally Directionally Drilled.

About 41 percent of the historic 5-year floodplain has become isolated, primarily due to flow alterations.

One ice jam was reported in the reach. It was a break-up flood event on March 17, 2011.

There are about 36 acres of mapped Russian olive in the reach.

Reach D14 was sampled as part of the avian study. A total of 30 bird species were identified in the reach. Two bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) on the Yellowstone River were found, the Ovenbird and the Plumbeous Vireo. Reach D14 has seen a decrease in the forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 25.6 acres per valley mile of such forest, and that number dropped to 19.6 acres per valley mile by 2001.

CEA-Related observations in Reach D14 include:
•Flow alteration impacts on floodplain access

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D14 include:
•Solid waste removal at dump sites at RM 25R, RM 24.3L, RM 17L, RM 15.8L, and RM 15.8R.
•Side channel reactivation at RM 23L
•Pipeline crossing Management at RM 27.
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No		6329500
Location	#Error	Sidney
Period of Record	#Error	1911-2015
Distance To (miles)	#Error	3.0

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated								NA	NA
Regulated								NA	NA
% Change								NA	NA

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1949	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1976	MDT	28-Oct-77	B/W	1:12,000	6329500	5800
1995	USGS DOQQ	28-Jul-95	B/W		6329500	25000
2001	NRCS	???	CIR	1:24,000	6329500	4000
2005	NAIP	07/14/2005	color	1-meter pixels	6329500	15900
2007	Woolpert	10/15/2007 - 11/2/0007	Color		6329500	
2009	NAIP	7/11/2009	Color	1-meter pixels	6329500	32600
2009	NAIP	7/9/2009	Color	1-meter pixels	6329500	35400
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/25/2011	Color	1-meter pixels	6329500	41100
2011	NAIP	7/15/2011	Color	1-meter pixels	6329500	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6329500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	1,613	1.1%	3,906	2.6%	2,293
	Flow Deflectors	935	0.6%	1,208	0.8%	273
	Between Flow Deflectors	1,297	0.9%	1,297	0.9%	0
	Feature Type Totals	**3,845**	**2.5%**	**6,411**	**4.2%**	**2,566**
	Reach Totals	**3,845**	**2.5%**	**6,411**	**4.2%**	**2,566**

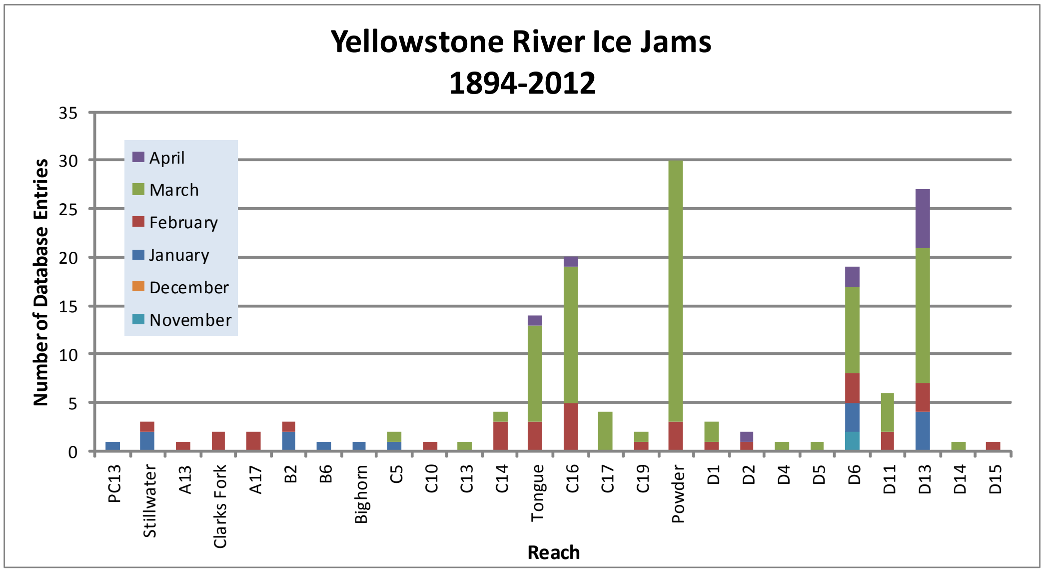
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	1,971	0	0	0	0	0	0	259
Rock RipRap	0	0	446	0	0	0	0	1,168
Totals	**1,971**	**0**	**446**	**0**	**0**	**0**	**0**	**1,427**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
3/17/2011	Break-up		

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter
1950	76,083	3,723	1.05
1976	75,267	28,654	1.38
1995	75,888	54,254	1.71
2001	75,901	32,508	1.43
Change 1950 - 2001	**-182**	**28,786**	**0.38**

	% Change in Braiding
1950 to 1976:	31.63%
1976 to 1995:	24.21%
1995 to 2001:	-16.71%
1950 to 2001:	36.17%

Length of Side Channels Blocked

Pre-1950s (ft)	3,595
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	1451	17.4%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	6895		3410	
Total Floodplain Area (Ac)	8346		4456	
Total Isolated (Ac)	**1451**	**17.4%**	**1046**	**40.9%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	132	0	33	**164**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
538	1,077	5,428	118	2%	633	0	0%

2011 Restricted Migration Area Summary

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	14	0.2%
RipRap/Flow Deflectors			
	Irrigated	1	0.0%
RipRap			
	Non-Irrigated	12	0.2%
	Exurban Industrial	69	1.1%
Flow Deflectors			
	Irrigated	65	1.1%
	Totals	**161**	**2.7%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
1586.3	0.0	93.1	113.0	10.9

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	49	98	143	153	0.5%	0.9%	1.3%	1.4%
	Totals	**49**	**98**	**143**	**153**	**0.5%**	**0.9%**	**1.3%**	**1.4%**
Agricultural Land									
	Non-Irrigated	4,570	3,488	3,179	3,085	42.6%	32.6%	29.7%	28.8%
	Irrigated	3,833	4,692	4,966	4,994	35.8%	43.8%	46.3%	46.6%
	Totals	**8,402**	**8,180**	**8,145**	**8,079**	**78.4%**	**76.3%**	**76.0%**	**75.4%**
Channel									
	Channel	2,199	2,353	2,196	2,249	20.5%	22.0%	20.5%	21.0%
	Totals	**2,199**	**2,353**	**2,196**	**2,249**	**20.5%**	**22.0%**	**20.5%**	**21.0%**
ExUrban									
	ExUrban Other	0	0	23	23	0.0%	0.0%	0.2%	0.2%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	15	135	139	0.0%	0.1%	1.3%	1.3%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**15**	**158**	**161**	**0.0%**	**0.1%**	**1.5%**	**1.5%**
Transportation									
	Public Road	62	66	70	70	0.6%	0.6%	0.7%	0.7%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	3	3	3	3	0.0%	0.0%	0.0%	0.0%
	Totals	**65**	**69**	**73**	**73**	**0.6%**	**0.6%**	**0.7%**	**0.7%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irr													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	436	1,003	0.0%	0.0%	5.3%	12.4%	0.0%	5.3%	7.1%	12.4%
	Flood	3,833	4,692	4,530	3,990	45.6%	57.4%	55.6%	49.4%	11.7%	-1.7%	-6.2%	3.8%
	Totals	**3,833**	**4,692**	**4,966**	**4,994**	**45.6%**	**57.4%**	**61.0%**	**61.8%**	**11.7%**	**3.6%**	**0.8%**	**16.2%**

NoIrr

Multi-Use	3,964	3,206	2,956	2,842	47.2%	39.2%	36.3%	35.2%	-8.0%	-2.9%	-1.1%	-12.0%
Hay/Pasture	606	283	223	243	7.2%	3.5%	2.7%	3.0%	-3.8%	-0.7%	0.3%	-4.2%
Totals	**4,570**	**3,488**	**3,179**	**3,085**	**54.4%**	**42.6%**	**39.0%**	**38.2%**	**-11.7%**	**-3.6%**	**-0.8%**	**-16.2%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.8	0.2	0.8	2.6	0.0	0.7	6.5	3.7	5.5
Max	500.7	159.2	118.8	246.1	421.8	478.2	28.9	8.4	13.3
Average	58.8	28.6	13.9	55.5	70.4	74.5	14.4	6.2	9.6
Sum	2,000.5	885.6	556.3	1,110.9	1,479.0	1,863.1	129.7	18.7	38.4

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	270.6
Channel to Riparian (acres)	729.7
Riparian Encroachment (acres)	**459.1**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	736.1
1950s Floodplain Mapped as 2011 Channel (Ac)	97.3
Total Recruitment (1950s to 2011)(Ac)	**833.4**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	8.1	137.1	144.3	0.0	**289.5**
Acres/Valley Mile	0.6	10.9	11.5	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	35.69	0.77%	53.75	0.15	15.92	0.02

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	805.0	536.5	24.0%
Rip Rap Bottom	149.6	127.5	5.7%
Rip Rap Margin	61.0	48.0	2.1%
Bluff Pool	71.9	69.6	3.1%
Terrace Pool	40.0	57.3	2.6%
Secondary Channel	53.2	73.2	3.3%
Secondary Channel (Seasonal)	232.9	175.0	7.8%
Channel Crossover	486.2	301.4	13.5%
Point Bar		65.0	2.9%
Side Bar		113.1	5.1%
Mid-channel Bar		138.6	6.2%
Island	337.6	337.6	15.1%
Dry Channel		191.5	8.6%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

Bird Species Observed in Reach/Region

Species of Concern

Potential Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
✓	✓	American Robin		✓	Chipping Sparrow	✓	✓	Killdeer		✓	Song Sparrow
✓	✓	American Crow		✓	Clay-collared Sparrow			Lark Bunting		✓	Spotted Sandpiper
✓	✓	American Goldfinch			Cliff Swallow		✓	Lark Sparrow	✓	✓	Spotted Towhee
	✓	American Kestrel		✓	Common Grackle	✓	✓	Lazuli Bunting			Sharp-shinned Hawk
✓	✓	American Redstart			Common Merganser	✓	✓	Least Flycatcher			Swainson's Thrush
	✓	Bald Eagle		✓	Common Nighthawk		✓	Mallard			Sandhill Crane
		Baltimore Oriole			Common Raven			Mountain Bluebird		✓	Tree Swallow
		Barn Swallow	✓	✓	Common Yellowthroat	✓	✓	Mourning Dove			Turkey Vulture
	✓	Belted Kingfisher		✓	Cooper's Hawk	✓	✓	Northern Flicker			Upland Sandpiper
	✓	Black-billed Cuckoo		✓	Dickcissel		✓	Orchard Oriole			Vesper Sparrow
	✓	Black-billed Magpie	✓	✓	Downy Woodpecker			Osprey			Violet-green Swallow
✓	✓	Black-capped Chickadee		✓	Eastern Bluebird	✓	✓	Ovenbird	✓	✓	Warbling Vireo
	✓	Black-and-white Warbler		✓	Eastern Kingbird	✓	✓	Plumbeous Vireo		✓	Western Kingbird
✓	✓	Black-headed Grosbeak			Eurasian Collared-dove		✓	Red-headed Woodpecker		✓	Western Meadowlark
✓	✓	Blue Jay		✓	European Starling			Red-naped Sapsucker	✓	✓	Western Wood-pewee
	✓	Bobolink		✓	Field Sparrow		✓	Red Crossbill	✓	✓	White-breasted Nuthatch
	✓	Brewer's Blackbird		✓	Franklin's Gull	✓	✓	Ring-necked Pheasant			White-throated Swift
✓	✓	Brown-headed Cowbird		✓	Grasshopper Sparrow		✓	Red-tailed hawk		✓	Wild Turkey
		Brown Creeper		✓	Gray Catbird		✓	Rock Dove		✓	Wood Duck
✓	✓	Brown Thrasher	✓	✓	Great Blue Heron	✓	✓	Red-winged Blackbird		✓	Yellow-bellied Sapsucker
	✓	Bullock's Oriole		✓	Great Horned Owl	✓	✓	Red-eyed Vireo		✓	Yellow-billed Cuckoo
		Canada Goose		✓	Hairy Woodpecker		✓	Red-breasted Grosbeak	✓	✓	Yellow-breasted Chat
✓	✓	Cedar Waxwing			House Finch			Say's Phoebe			Yellow-headed Blackbird
	✓	Chimney Swift	✓	✓	House Wren		✓	Savannah Sparrow	✓	✓	Yellow Warbler

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.

There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

Yellowstone River Reach Narratives — Reach D15

County	Mckenzie	**Upstream River Mile**	13.5
Classification	PCM/I: Partially confined meandering/islands	**Downstream River Mile**	7.5
General Location	Downstream of Fairview	**Length**	6.00 mi (9.66 km)

General Comments

Narrative Summary

Reach D15 is located downstream of Fairview. The reach is a 6 mile long Partially Confined Meandering with Islands (PCM/I), indicating some valley wall influence, and a meandering main thread with cutoff channels through meander cores forming persistent forested islands.

No bank armor was mapped in the reach, and no side channels have been blocked.

Similar to many reaches in the Lower Yellowstone Valley, the river channel in Reach D15 has gotten smaller since 1950. The channel contracted by about 190 acres in this reach since 1950, and about 210 acres of riparian vegetation has encroached into old channel areas. This pattern has been consistent in the lower river, and relates primarily to a reduction in flows due to human development.

Land use is predominantly agricultural, with 71 acres of pivot irrigation development since 1950. A total of 54 percent of the 100 year floodplain has become isolated (1,885 acres), and most of this isolation is from agricultural dikes. Approximately 23 percent of the 5-year floodplain has become isolated (168 acres).

There is a drill pad on the edge of the CMZ at RM 10.8L.

One ice jam was reported in the reach. It was a break-up flood event on February 12, 1996.

Reach D15 was sampled as part of the avian study. A total of 30 bird species were identified in the reach. Two bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) on the Yellowstone River were found, the Ovenbird and the Plumbeous Vireo.. Reach D15 has seen a decrease in the forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 25.6 acres per valley mile of such forest, and that number dropped to 19.6 acres per valley mile by 2001.

CEA-Related observations in Reach D15 include:
•Flow alteration impacts on floodplain access

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D15 include:
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No		6329500
Location	#Error	Sidney
Period of Record	#Error	1911-2015
Distance To (miles)	#Error	17.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated								NA	NA
Regulated								NA	NA
% Change								NA	NA

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6329500	2750
1995	USGS DOQQ	1995??	B/W		6329500	
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6329500	4000
2007	Woolpert	10/15/2007 - 11/2/0007	Color		6329500	
2009	NAIP	7/9/2009	Color	1-meter pixels	6329500	35400
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/25/2011	Color	1-meter pixels	6329500	41100

PHYSICAL FEATURES

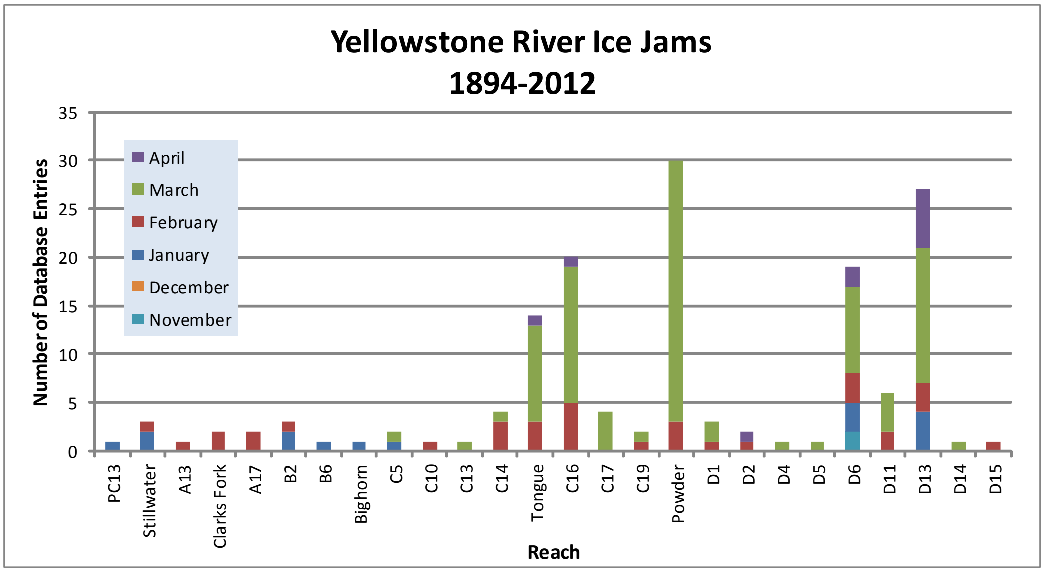
Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



Jam Date	Jam Type	River Mile	Damages
2/12/1996	Break-up	10	?

GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	31,574	14,376	1.46	1950 to 1976:	
1976				1976 to 1995:	
1995	31,054	33,170	2.07	1995 to 2001:	-5.23%
2001	31,573	30,311	1.96	1950 to 2001:	34.68%
Change 1950 - 2001	**-1**	**15,935**	**0.50**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	1885	54.4%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1581		1372	
Total Floodplain Area (Ac)	3466		1540	
Total Isolated (Ac)	**1885**	**54.4%**	**168**	**22.7%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	56	0	0	**56**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
226	452	1,776	20	1%	0	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	4	0.2%
	Exurban Other	17	1.0%
	Totals	**21**	**1.2%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
240.7	0.0	4.4	10.2	1.1

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0		0	0	0.0%		0.0%	0.0%
	Agricultural Roads	0		0	0	0.0%		0.0%	0.0%
	Other Infrastructure	86		188	193	1.0%		2.1%	2.1%
	Totals	**86**		**188**	**193**	**1.0%**		**2.1%**	**2.1%**
Agricultural Land									
	Non-Irrigated	2,260		1,320	1,313	25.1%		14.7%	14.6%
	Irrigated	3,955		6,173	6,173	44.0%		68.6%	68.6%
	Totals	**6,215**		**7,492**	**7,485**	**69.1%**		**83.3%**	**83.2%**
Channel									
	Channel	1,130		1,212	1,214	12.6%		13.5%	13.5%
	Totals	**1,130**		**1,212**	**1,214**	**12.6%**		**13.5%**	**13.5%**
ExUrban									
	ExUrban Other	0		29	29	0.0%		0.3%	0.3%
	ExUrban Undeveloped	0		0	0	0.0%		0.0%	0.0%
	ExUrban Industrial	0		7	7	0.0%		0.1%	0.1%
	ExUrban Commercial	0		0	0	0.0%		0.0%	0.0%
	ExUrban Residential	0		0	0	0.0%		0.0%	0.0%
	Totals	**0**		**36**	**36**	**0.0%**		**0.4%**	**0.4%**
Transportation									
	Public Road	79		71	71	0.9%		0.8%	0.8%
	Interstate	0		0	0	0.0%		0.0%	0.0%
	Railroad	0		0	0	0.0%		0.0%	0.0%
	Totals	**79**		**71**	**71**	**0.9%**		**0.8%**	**0.8%**
Urban									
	Urban Other	0		0	0	0.0%		0.0%	0.0%
	Urban Residential	0		0	0	0.0%		0.0%	0.0%
	Urban Commercial	0		0	0	0.0%		0.0%	0.0%
	Urban Undeveloped	0		0	0	0.0%		0.0%	0.0%
	Urban Industrial	0		0	0	0.0%		0.0%	0.0%
	Totals	**0**		**0**	**0**	**0.0%**		**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irr													
	Sprinkler	0		0	0	0.0%		0.0%	0.0%		0.0%	0.0%	0.0%
	Pivot	0		20	71	0.0%		0.3%	1.0%		0.3%	0.7%	1.0%
	Flood	3,955		6,153	6,101	63.6%		82.1%	81.5%		18.5%	-0.6%	17.9%
	Totals	**3,955**		**6,173**	**6,173**	**63.6%**		**82.4%**	**82.5%**		**18.8%**	**0.1%**	**18.8%**

NoIrr

Multi-Use	1,804	1,307	1,300	29.0%	17.4%	17.4%	-11.6%	-0.1%	-11.7%
Hay/Pasture	456	13	13	7.3%	0.2%	0.2%	-7.2%	0.0%	-7.2%
Totals	**2,260**	**1,320**	**1,313**	**36.4%**	**17.6%**	**17.5%**	**-18.8%**	**-0.1%**	**-18.8%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.2		1.8	7.7		1.8	13.7		3.6
Max	120.5		39.0	121.8		199.0	35.0		16.2
Average	35.5		12.0	46.0		39.9	22.7		9.9
Sum	568.0		228.1	322.1		678.8	90.8		19.8

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	93.5
Channel to Riparian (acres)	302.0
Riparian Encroachment (acres)	**208.5**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	304.4
1950s Floodplain Mapped as 2011 Channel (Ac)	77.3
Total Recruitment (1950s to 2011)(Ac)	**381.7**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	1.6	20.2	68.7	0.0	**90.5**
Acres/Valley Mile	0.3	3.5	11.9	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.83	0.10%	5.72	0.00	0.00	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	197.2	191.0	15.8%
Rip Rap Bottom	133.0	79.1	6.5%
Rip Rap Margin	38.3	34.6	2.9%
Bluff Pool	64.3	43.7	3.6%
Terrace Pool	101.9	36.7	3.0%
Secondary Channel		30.9	2.6%
Secondary Channel (Seasonal)	71.0	68.4	5.6%
Channel Crossover	190.0	133.8	11.0%
Side Bar		124.6	10.3%
Mid-channel Bar		52.1	4.3%
Island	413.3	413.3	34.1%
Dry Channel		3.9	0.3%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.

Yellowstone River Reach Narratives — Reach D16

County	Mckenzie	**Upstream River Mile**	7.5
Classification	US/I: Unconfined straight/islands	**Downstream River Mile**	0
General Location	To Missouri River	**Length**	7.50 mi (12.07 km)
General Comments	To mouth: low sinuosity; alternate bars; vegetated islands		

Narrative Summary

Reach D16 is the lowermost reach of the Yellowstone River, extending 7.5 miles to the confluence with the Missouri River. It is a unique reach type, referred to as Unconfined Straight (US), and it has numerous forested islands that have developed since the 1950s.

Reach D16 has only a few hundred feet of rock riprap along its 7.5 mile length, and all of that was built since 2001. No side channels have been blocked.

The most striking change in Reach D16 since 1950 is the encroachment of riparian vegetation onto old sand bars. Between 1950 and 2001, the size of the channel has dropped by 550 acres, and there has been 472 acres of riparian encroachment into old channel areas. Much of this encroachment converted open sand bars into forested islands. There has been a loss of over 150 acres of sand bar since 1950. This change has resulted in a conversion of almost 7 miles low flow channels around gravel bars to anabranching side channels around islands.

Land use in the reach is dominated by flood irrigation. The extent of flood irrigated lands increased from 4,600 acres in 1950 to about 8,500 acres in 2011. The floodplain is very flat and broad in this lowermost portion of the Yellowstone River valley, and as a result, floodplain development for agriculture has substantially altered floodplain access. About 29 percent of the 100-year floodplain has become isolated from the river, and a fraction of this (1.6 percent) has been attributed to flow alterations, whereas 27 percent has been associated with agricultural features on the floodplain such as roads and ditches. There are about 480 acres of flood irrigated land within the Channel Migration Zone of Reach D16.

Land use mapping shows several drill pads in the lower portion of the reach that are within several thousand feet of the river. There are four drill pads on a narrow strip of land at the mouth that lies between the Yellowstone and Missouri Rivers.

Reach D16 has a notably high concentration of mapped wetlands. There are about 580 acres of mapped wetland in the reach, which translates to about 80 acres per valley mile. Along the rest of the river, wetland densities rarely exceed 50 acres per valley mile. Reach D16 only has 3.5 acres of mapped Russian olive, which is a relatively low density for reaches below Billings.

Because of the riparian encroachment, Reach D16 has seen an increase in the area of riparian forest considered at low risk of cowbird parasitism; in 1950 there were about 250 acres of such forest per valley mile, and in 2001 there were 308 acres per valley mile.

The changes in Reach D16 are due in part to major flow alterations in the reach. The 2-year discharge, which is considered to have a large influence on channel size, has been reduced by 22 percent due to human development.

CEA-Related observations in Reach D16 include:
•Extensive riparian encroachment with flow alterations
•Conversion of open sand bars to forested islands

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach D16 include:
•Drill pad considerations
•Riparian protections

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Sidney

Flood History

Year	Date	Flow on Date	Return Interval
1978	May 23	111,000	10-25 yr
1912	Mar 29	114,000	10-25 yr
1944	Jun 21	120,000	10-25 yr
2011	May 24	124,000	10-25 yr
1918	Jun 20	126,000	25-50 yr
1943	Mar 29	132,000	25-50 yr
1923	Oct 3	134,000	25-50 yr
1952	Mar 31	138,000	25-50 yr
1921	Jun 21	159,000	100-yr

	Downstream Gage	Upstream Gage
Gage No		6329500
Location	#Error	Sidney
Period of Record	#Error	1911-2015
Distance To (miles)	#Error	23.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated								NA	NA
Regulated								NA	NA
% Change								NA	NA

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	???	???	B/W		6329500	
1995	USGS DOQQ	???	B/W		6329500	
2007	Woolpert	10/15/2007 - 11/2/0007	Color		6329500	
2011	USCOE	October 2012	color	1-ft pixel	6329500	9030
2011	NAIP	7/25/2011	Color	1-meter pixels	6329500	41100

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

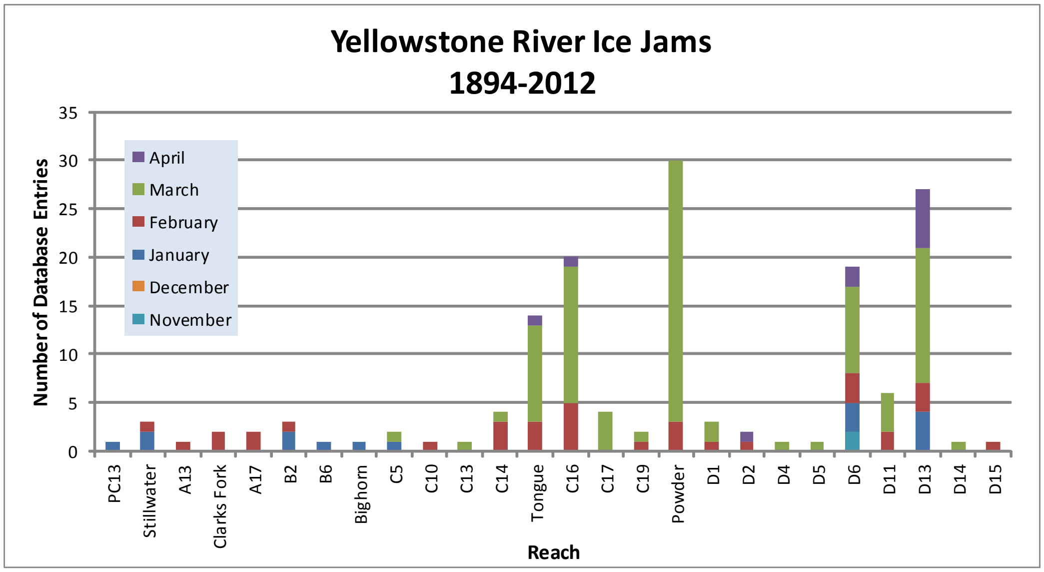
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	0	0.0%	266	0.3%	266
	Feature Type Totals		**0.0%**	**266**	**0.3%**	
	Reach Totals		**0.0%**	**266**	**0.3%**	

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	39,537	8,696	1.22	**1950 to 1976:**	
1976				**1976 to 1995:**	
1995	39,507	52,163	2.32	**1995 to 2001:**	-8.63%
2001	39,089	43,781	2.12	**1950 to 2001:**	73.78%
Change 1950 - 2001	**-448**	**35,086**	**0.90**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	22	1.6%		
Agriculture (generally relates to field boundaries)	369	27.7%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	939		1193	
Total Floodplain Area (Ac)	1330		1298	
Total Isolated (Ac)	**390**	**29.4%**	**106**	**31.3%**

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	8	0	0	**8**

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
481.7	0.0	0.0	0.0	0.0

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0		0	0	0.0%		0.0%	0.0%
	Agricultural Roads	0		0	0	0.0%		0.0%	0.0%
	Other Infrastructure	87		229	270	0.5%		1.4%	1.7%
	Totals	**87**		**229**	**270**	**0.5%**		**1.4%**	**1.7%**
Agricultural Land									
	Non-Irrigated	5,841		5,977	5,870	36.3%		37.2%	36.5%
	Irrigated	4,631		8,513	8,492	28.8%		53.0%	52.8%
	Totals	**10,472**		**14,490**	**14,362**	**65.1%**		**90.1%**	**89.3%**
Channel									
	Channel	1,547		1,334	1,361	9.6%		8.3%	8.5%
	Totals	**1,547**		**1,334**	**1,361**	**9.6%**		**8.3%**	**8.5%**
ExUrban									
	ExUrban Other	0		0	0	0.0%		0.0%	0.0%
	ExUrban Undeveloped	0		0	0	0.0%		0.0%	0.0%
	ExUrban Industrial	0		4	64	0.0%		0.0%	0.4%
	ExUrban Commercial	0		0	0	0.0%		0.0%	0.0%
	ExUrban Residential	0		0	0	0.0%		0.0%	0.0%
	Totals	**0**		**4**	**64**	**0.0%**		**0.0%**	**0.4%**
Transportation									
	Public Road	0		18	18	0.0%		0.1%	0.1%
	Interstate	0		0	0	0.0%		0.0%	0.0%
	Railroad	0		0	0	0.0%		0.0%	0.0%
	Totals	**0**		**18**	**18**	**0.0%**		**0.1%**	**0.1%**
Urban									
	Urban Other	0		0	0	0.0%		0.0%	0.0%
	Urban Residential	0		0	0	0.0%		0.0%	0.0%
	Urban Commercial	0		0	0	0.0%		0.0%	0.0%
	Urban Undeveloped	0		0	0	0.0%		0.0%	0.0%
	Urban Industrial	0		0	0	0.0%		0.0%	0.0%
	Totals	**0**		**0**	**0**	**0.0%**		**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irr													
	Sprinkler	0		0	0	0.0%		0.0%	0.0%		0.0%	0.0%	0.0%
	Pivot	0		0	0	0.0%		0.0%	0.0%		0.0%	0.0%	0.0%
	Flood	4,631		8,513	8,492	44.2%		58.7%	59.1%		14.5%	0.4%	14.9%
	Totals	**4,631**		**8,513**	**8,492**	**44.2%**		**58.7%**	**59.1%**		**14.5%**	**0.4%**	**14.9%**

NoIrr

Multi-Use	5,423	5,308	5,281	51.8%	36.6%	36.8%	-15.2%	0.1%	-15.0%
Hay/Pasture	418	670	589	4.0%	4.6%	4.1%	0.6%	-0.5%	0.1%
Totals	**5,841**	**5,977**	**5,870**	**55.8%**	**41.3%**	**40.9%**	**-14.5%**	**-0.4%**	**-14.9%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**	**1950**	**1976**	**2001**
Min	0.5		1.7	0.6		2.5	3.3		5.3
Max	379.8		185.8	930.0		891.6	31.5		60.8
Average	44.8		26.0	141.0		95.7	13.2		20.1
Sum	1,971.6		988.8	2,537.5		2,965.9	66.1		201.3

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	296.8
Channel to Riparian (acres)	769.0
Riparian Encroachment (acres)	**472.2**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	757.5
1950s Floodplain Mapped as 2011 Channel (Ac)	117.7
Total Recruitment (1950s to 2011)(Ac)	**875.2**

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	25.3	254.9	278.2	21.7	**580.0**
Acres/Valley Mile	3.6	36.2	39.5	3.1	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	3.48	0.07%	6.30	0.00	0.00	0.00

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	575.6	457.3	34.3%
Secondary Channel		12.5	0.9%
Secondary Channel (Seasonal)	216.4	152.0	11.4%
Channel Crossover	162.6	117.9	8.8%
Point Bar		10.3	0.8%
Side Bar		78.9	5.9%
Mid-channel Bar		53.1	4.0%
Island	379.1	379.1	28.4%
Dry Channel		72.8	5.5%

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region D

A review of the interview data for the segment, Missouri River to Powder River, suggests that people in this area engage in four primary discussions when asked about the Yellowstone River. First, the notion of Eastern Montana is not simply a geographic reference. It is a defining concept that captures the agricultural roots and the cultural values of the people living in the study segment, and the river is an essential element within their notion of Eastern Montana. Second, the river is discussed as a wholesome recreational outlet. However, shifting landownership is noted as an important change in the recreational context. Third, even though agricultural practices are viewed as the mainstay of the local economies, many participants discuss the long-term economic viability of their communities as a concern. Industrial and residential developments along the river's edge are seemingly remote possibilities and are generally discussed with references to flood plain restrictions and the stability of nearby dikes. Finally, discussions of managing the river are limited, but a variety of opinions are offered regarding bank erosion and stabilization techniques.