

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:

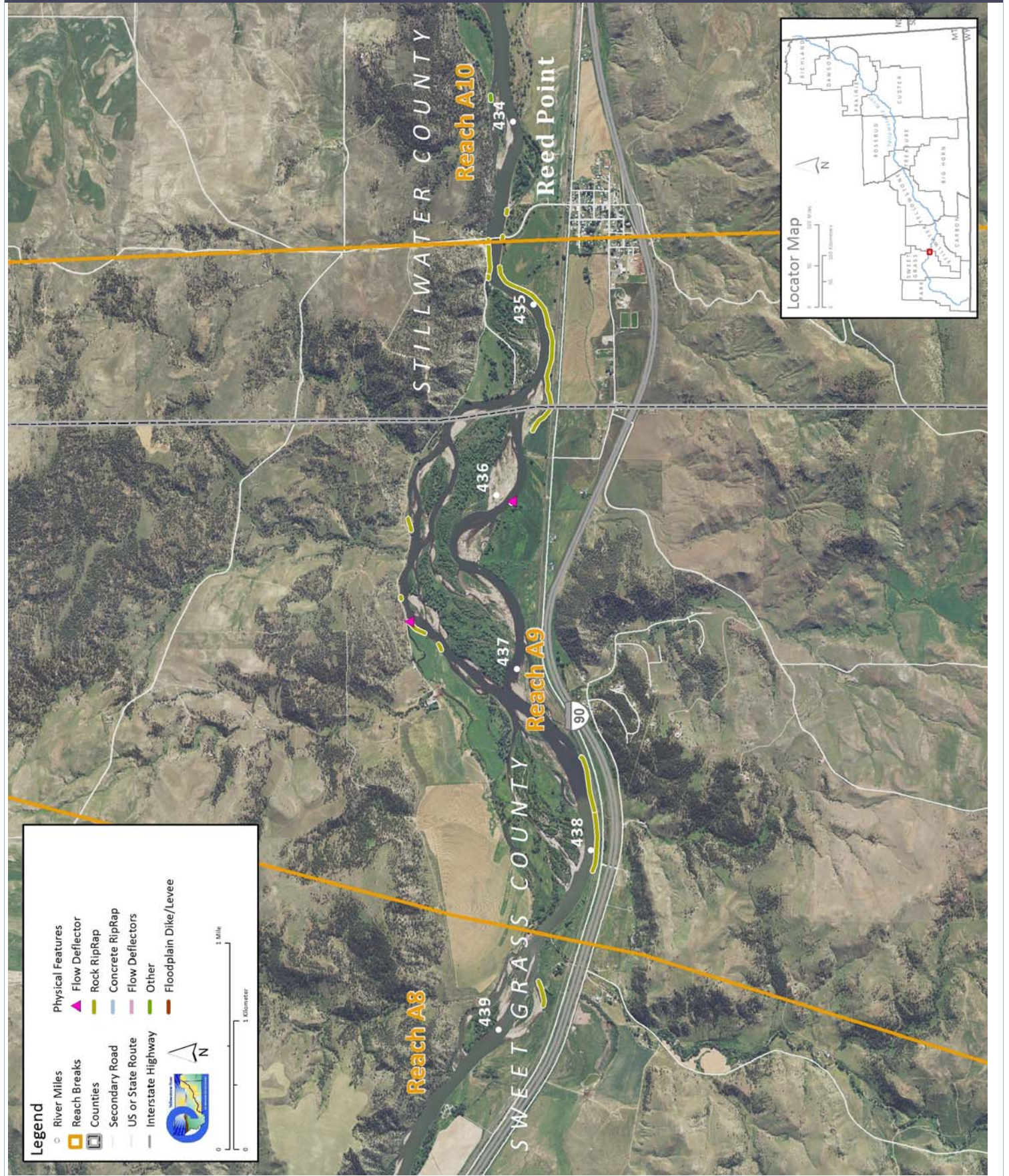
- Reduced floodplain turnover rates since 1976
- Approximately 3,700 feet of side channel has been lost due to channel plugging between 1950 and 2011
- Meander belt encroachment at bridge crossing
- Side channel loss as part of armoring at bridge approach

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	Gage No	Downstream Gage	Upstream Gage
1971	Jun 23	29,200	10-25 yr		6214500	6192500
1902	Jun 11	30,100	10-25 yr		Billings	Livingston
1943	Jun 20	30,600	10-25 yr		1929-2015	1929-2015
1974	Jun 17	36,300	50-100 yr		Distance To (miles)	70.3
1996	Jun 10	37,100	50-100 yr			68.1
1997	Jun 6	38,000	50-100 yr			
2011	Jun 30	40,600	>100-yr			

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 discrepancies 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

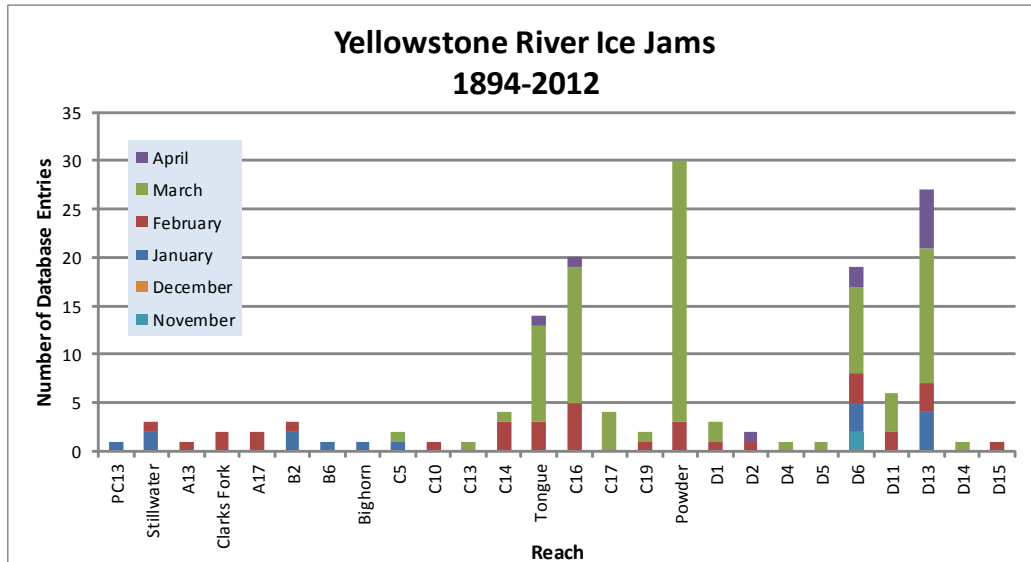
Intent of Bank Protection: 2001

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 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 (isolated 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 agriculture 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

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	3	0.3%
RipRap			
	Railroad	148	12.8%
Totals		151	13.1%

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Transportation
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

Feature Class	Feature Type	Acres				% of Reach Area			
		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

Feature Class	Feature Type	Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
		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

Statistic	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
	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 (YRDC) 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 developed 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.

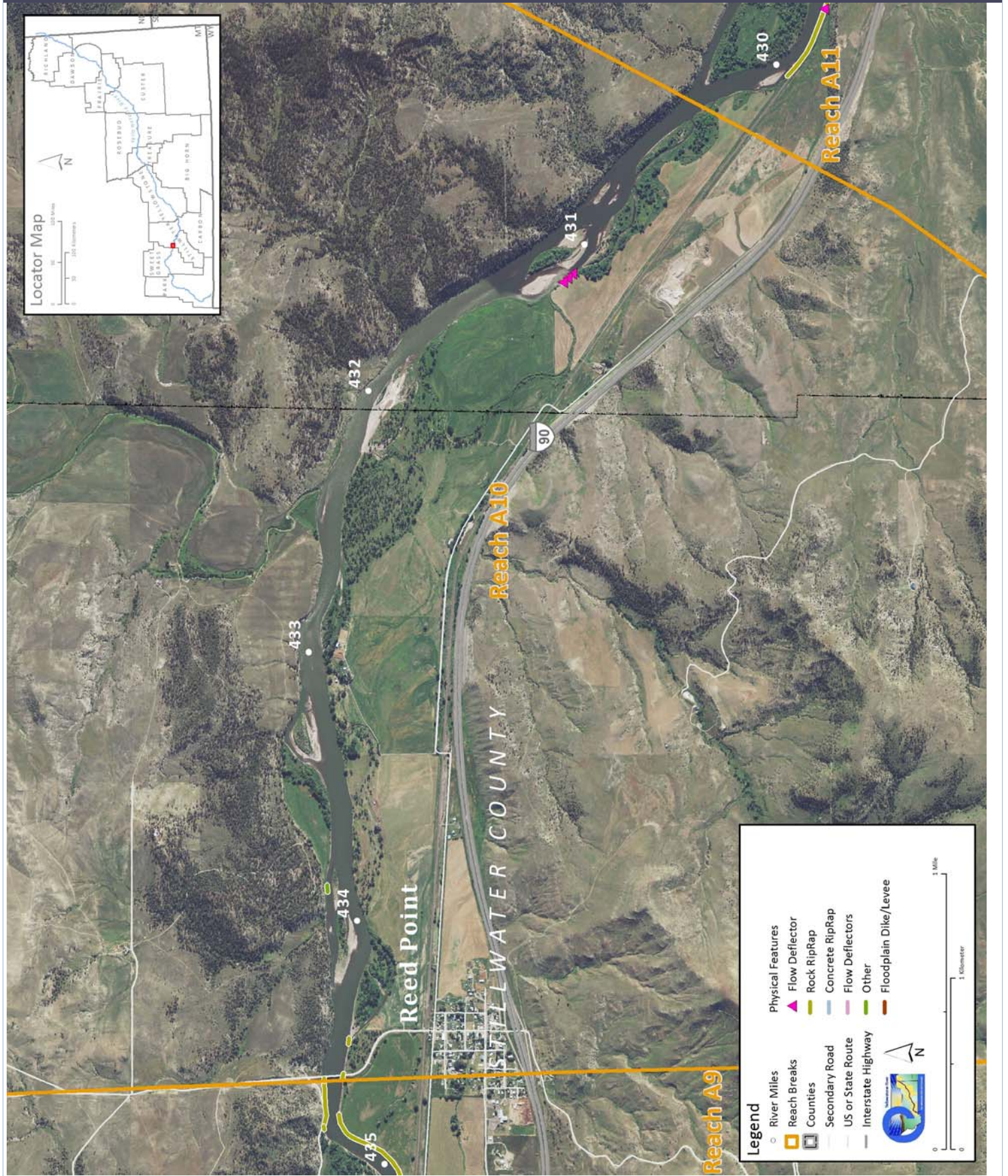
CEA-Related observations in Reach A10 include:

- 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	Gage No	Downstream Gage	Upstream Gage
1971	Jun 23	29,200	10-25 yr	6214500	6192500	6192500
1902	Jun 11	30,100	10-25 yr	Billings	Billings	Livingston
1943	Jun 20	30,600	10-25 yr	1929-2015	1929-2015	1929-2015
1974	Jun 17	36,300	50-100 yr	Distance To (miles)	65.9	71.9
1996	Jun 10	37,100	50-100 yr			
1997	Jun 6	38,000	50-100 yr			
2011	Jun 30	40,600	>100-yr			

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 discrepancies 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

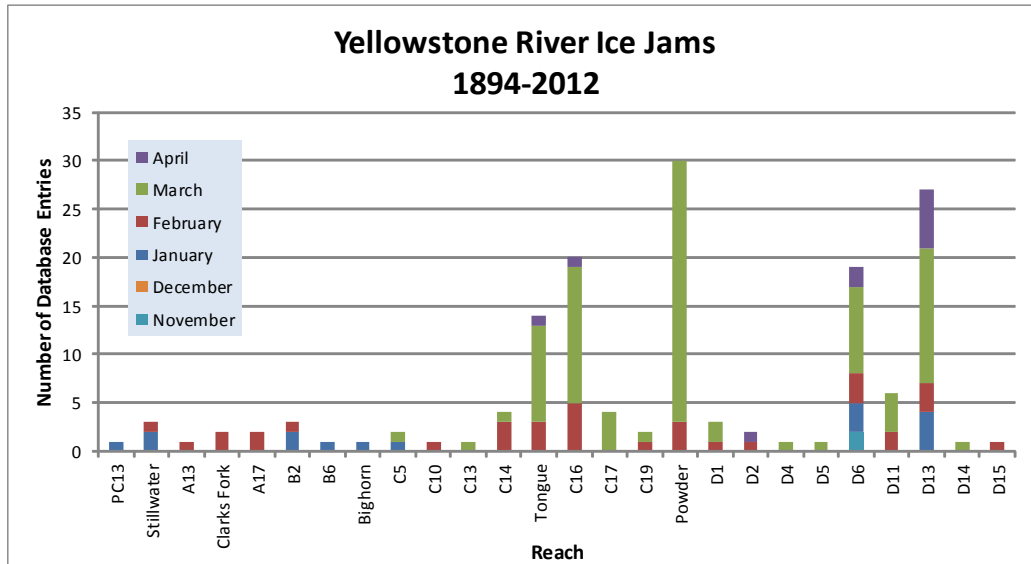
Bankline/Floodplain Inventory: Time Series

The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

Feature Class	Feature Type	Sum of Feature Length (ft)					
		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 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 (isolated 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 agriculture 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	Transportation
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

Feature Class	Feature Type	Acres				% of Reach Area			
		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

Feature Class	Feature Type	Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
		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

Statistic	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
	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 (YRDC) 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 developed 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:

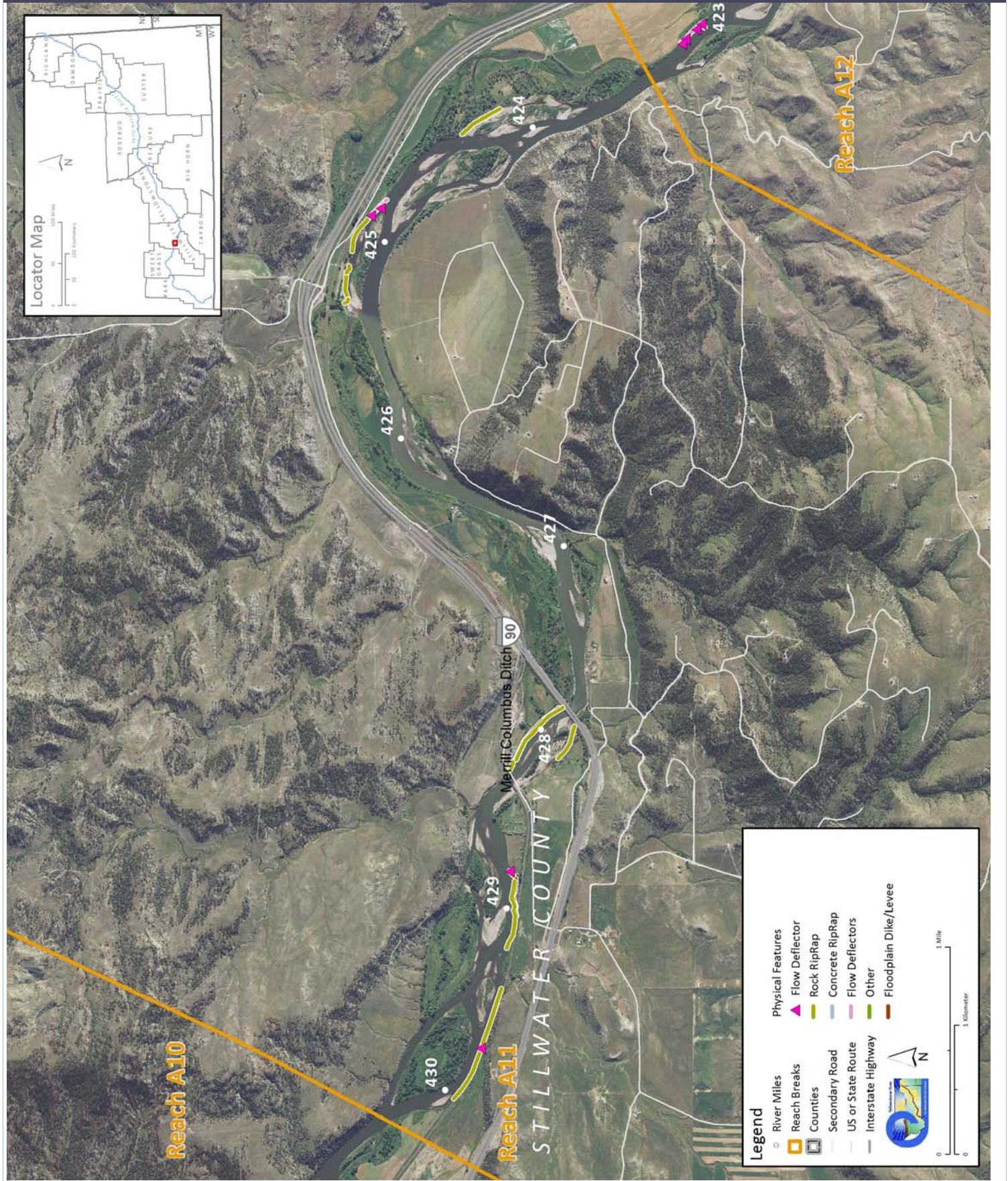
- Accelerated erosion behind 1,000 feet of flanked rock riprap.
- Blockage of several thousand feet of side channel
- At least one flanked barb
- Expansion of Russian olive infestation relative to upstream.
- Reduction in both closed timber and shrub riparian extent.

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	Gage No	Downstream Gage	Upstream Gage
1971	Jun 23	29,200	10-25 yr	6214500	6192500	6192500
1902	Jun 11	30,100	10-25 yr	Billings	Billings	Livingston
1943	Jun 20	30,600	10-25 yr	1929-2015	1929-2015	1929-2015
1974	Jun 17	36,300	50-100 yr	Distance To (miles)	58.9	76.3
1996	Jun 10	37,100	50-100 yr			
1997	Jun 6	38,000	50-100 yr			
2011	Jun 30	40,600	>100-yr			

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 discrepancies 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

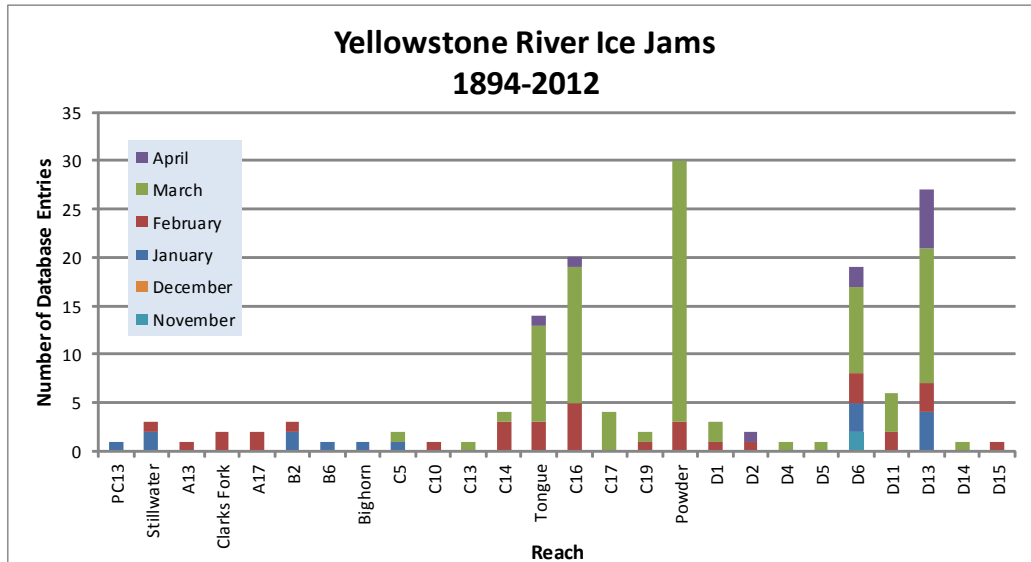
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

Feature Class	Feature Type	Sum of Feature Length (ft)					
		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 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 (isolated 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 agriculture 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

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	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%

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ExUrban	Transportation
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

Feature Class	Feature Type	Acres				% of Reach Area			
		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

Feature Class	Feature Type	Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
		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

Statistic	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
	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 (YRDC) 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 developed 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
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Robin	<input type="checkbox"/> <input checked="" type="checkbox"/> Chipping Sparrow	<input type="checkbox"/> <input type="checkbox"/> Killdeer	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Song Sparrow
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Crow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Clay-collared Sparrow	<input type="checkbox"/> <input type="checkbox"/> Lark Bunting	<input type="checkbox"/> <input type="checkbox"/> Spotted Sandpiper
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Goldfinch	<input type="checkbox"/> <input checked="" type="checkbox"/> Cliff Swallow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Lark Sparrow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Spotted Towhee
<input type="checkbox"/> <input type="checkbox"/> American Kestrel	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Common Grackle	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Lazuli Bunting	<input type="checkbox"/> <input type="checkbox"/> Sharp-shinned Hawk
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Redstart	<input type="checkbox"/> <input type="checkbox"/> Common Merganser	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Least Flycatcher	<input type="checkbox"/> <input checked="" type="checkbox"/> Swainson's Thrush
<input type="checkbox"/> <input type="checkbox"/> Bald Eagle	<input type="checkbox"/> <input type="checkbox"/> Common Nighthawk	<input type="checkbox"/> <input type="checkbox"/> Mallard	<input type="checkbox"/> <input type="checkbox"/> Sandhill Crane
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Baltimore Oriole	<input type="checkbox"/> <input type="checkbox"/> Common Raven	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Mountain Bluebird	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Tree Swallow
<input type="checkbox"/> <input checked="" type="checkbox"/> Barn Swallow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Common Yellowthroat	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Mourning Dove	<input type="checkbox"/> <input type="checkbox"/> Turkey Vulture
<input type="checkbox"/> <input type="checkbox"/> Belted Kingfisher	<input type="checkbox"/> <input type="checkbox"/> Cooper's Hawk	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Northern Flicker	<input type="checkbox"/> <input type="checkbox"/> Upland Sandpiper
<input type="checkbox"/> <input type="checkbox"/> Black-billed Cuckoo	<input type="checkbox"/> <input checked="" type="checkbox"/> Dickcissel	<input type="checkbox"/> <input type="checkbox"/> Orchard Oriole	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Vesper Sparrow
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-billed Magpie	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Downy Woodpecker	<input type="checkbox"/> <input type="checkbox"/> Osprey	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Violet-green Swallow
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-capped Chickadee	<input type="checkbox"/> <input type="checkbox"/> Eastern Bluebird	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Ovenbird	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Warbling Vireo
<input type="checkbox"/> <input checked="" type="checkbox"/> Black-and-white Warbler	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Eastern Kingbird	<input type="checkbox"/> <input type="checkbox"/> Plumbeous Vireo	<input type="checkbox"/> <input checked="" type="checkbox"/> Western Kingbird
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-headed Grosbeak	<input type="checkbox"/> <input type="checkbox"/> Eurasian Collared-dove	<input type="checkbox"/> <input type="checkbox"/> Red-headed Woodpecker	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Western Meadowlark
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Blue Jay	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> European Starling	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Red-naped Sapsucker	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Western Wood-pewee
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Bobolink	<input type="checkbox"/> <input checked="" type="checkbox"/> Field Sparrow	<input type="checkbox"/> <input type="checkbox"/> Red Crossbill	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> White-breasted Nuthatch
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Brewer's Blackbird	<input type="checkbox"/> <input type="checkbox"/> Franklin's Gull	<input type="checkbox"/> <input type="checkbox"/> Ring-necked Pheasant	<input type="checkbox"/> <input checked="" type="checkbox"/> White-throated Swift
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Brown-headed Cowbird	<input type="checkbox"/> <input type="checkbox"/> Grasshopper Sparrow	<input type="checkbox"/> <input type="checkbox"/> Red-tailed hawk	<input type="checkbox"/> <input type="checkbox"/> Wild Turkey
<input type="checkbox"/> <input type="checkbox"/> Brown Creeper	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Gray Catbird	<input type="checkbox"/> <input type="checkbox"/> Rock Dove	<input type="checkbox"/> <input type="checkbox"/> Wood Duck
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Brown Thrasher	<input type="checkbox"/> <input type="checkbox"/> Great Blue Heron	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Red-winged Blackbird	<input type="checkbox"/> <input type="checkbox"/> Yellow-bellied Sapsucker
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Bullock's Oriole	<input type="checkbox"/> <input type="checkbox"/> Great Horned Owl	<input type="checkbox"/> <input checked="" type="checkbox"/> Red-eyed Vireo	<input type="checkbox"/> <input type="checkbox"/> Yellow-billed Cuckoo
<input type="checkbox"/> <input type="checkbox"/> Canada Goose	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Hairy Woodpecker	<input type="checkbox"/> <input type="checkbox"/> Red-breasted Grosbeak	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Yellow-breasted Chat
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Cedar Waxwing	<input type="checkbox"/> <input type="checkbox"/> House Finch	<input type="checkbox"/> <input type="checkbox"/> Say's Phoebe	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Yellow-headed Blackbird
<input type="checkbox"/> <input checked="" type="checkbox"/> Chimney Swift	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> House Wren	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Savannah Sparrow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> 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 Dickcissel, 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.

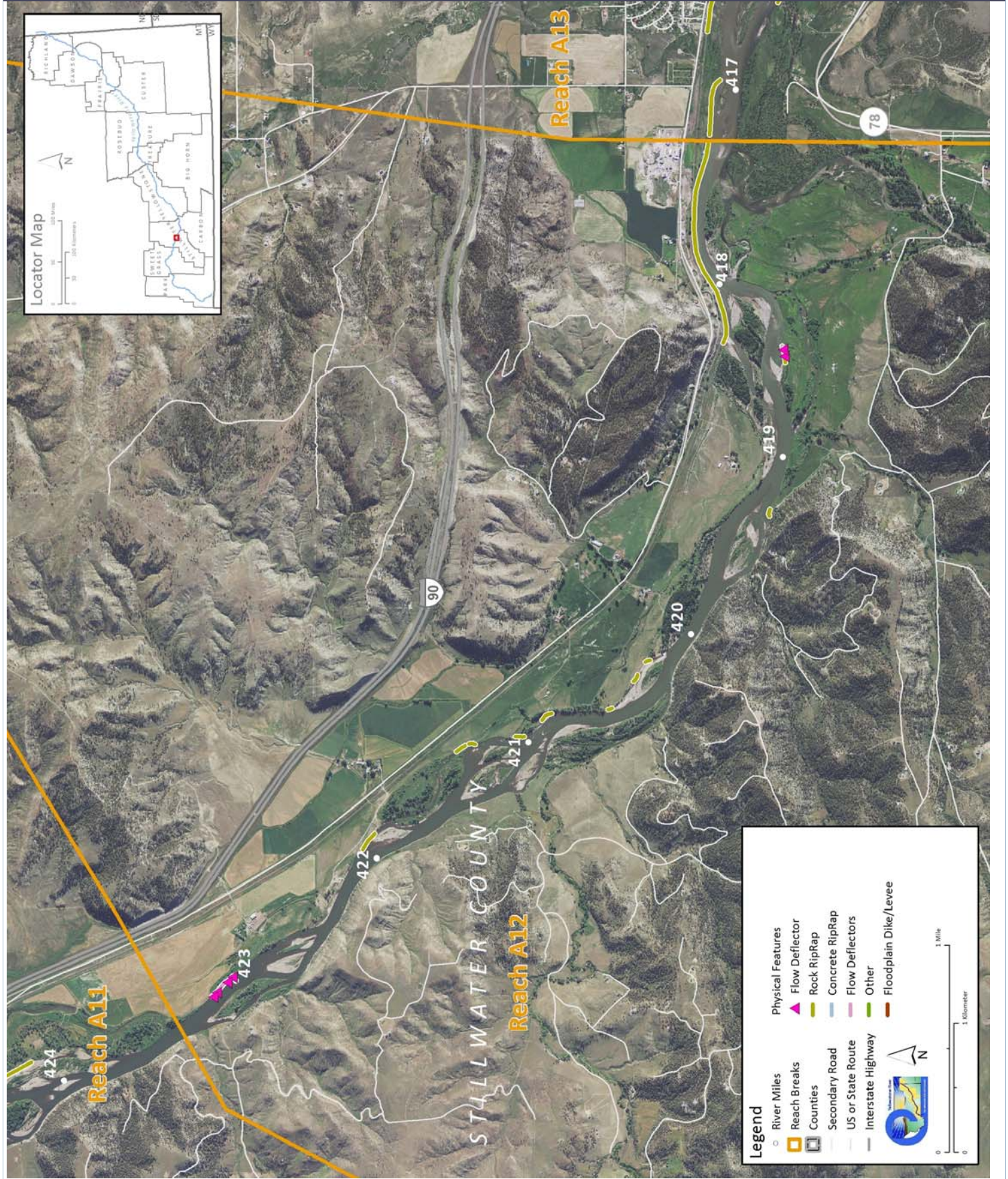
CEA-Related observations in Reach A12 include:

- 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	Gage No	Downstream Gage	Upstream Gage
1971	Jun 23	29,200	10-25 yr		6214500	6192500
1902	Jun 11	30,100	10-25 yr		Billings	Livingston
1943	Jun 20	30,600	10-25 yr		1929-2015	1929-2015
1974	Jun 17	36,300	50-100 yr		Distance To (miles)	52.9
1996	Jun 10	37,100	50-100 yr			83.3
1997	Jun 6	38,000	50-100 yr			
2011	Jun 30	40,600	>100-yr			

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 discrepancies 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

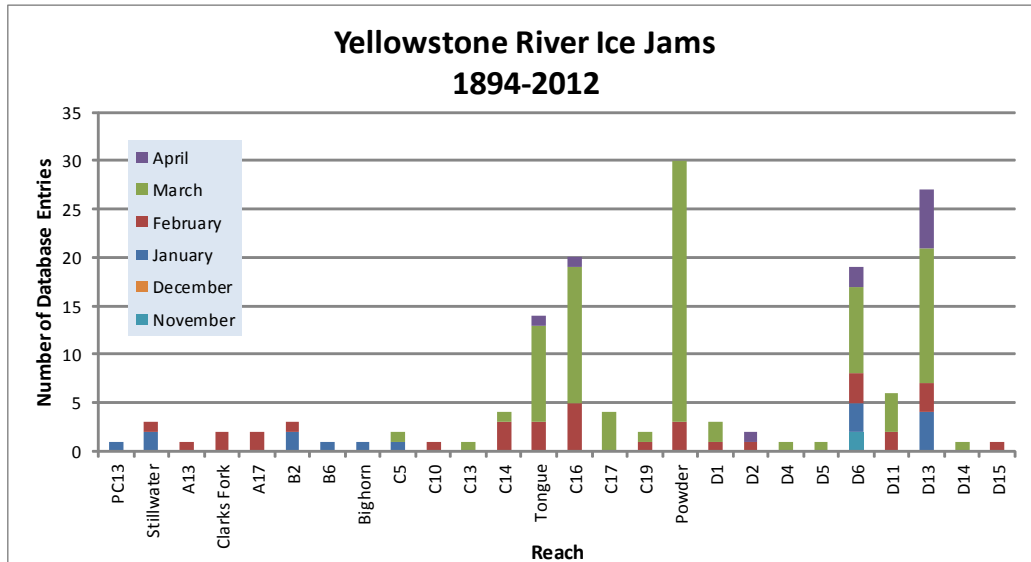
Bankline/Floodplain Inventory: Time Series

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 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 (isolated 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 agriculture 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	Transportation
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

Feature Class	Feature Type	Acres				% of Reach Area			
		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

Feature Class	Feature Type	Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
		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

Statistic	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
	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 (YRCD) 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 developed 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
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Robin	<input type="checkbox"/> <input checked="" type="checkbox"/> Chipping Sparrow	<input type="checkbox"/> <input type="checkbox"/> Killdeer	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Song Sparrow
<input type="checkbox"/> <input checked="" type="checkbox"/> American Crow	<input type="checkbox"/> <input checked="" type="checkbox"/> Clay-collared Sparrow	<input type="checkbox"/> <input type="checkbox"/> Lark Bunting	<input type="checkbox"/> <input type="checkbox"/> Spotted Sandpiper
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Goldfinch	<input type="checkbox"/> <input checked="" type="checkbox"/> Cliff Swallow	<input type="checkbox"/> <input checked="" type="checkbox"/> Lark Sparrow	<input type="checkbox"/> <input checked="" type="checkbox"/> Spotted Towhee
<input type="checkbox"/> <input type="checkbox"/> American Kestrel	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Common Grackle	<input type="checkbox"/> <input checked="" type="checkbox"/> Lazuli Bunting	<input type="checkbox"/> <input type="checkbox"/> Sharp-shinned Hawk
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Redstart	<input type="checkbox"/> <input type="checkbox"/> Common Merganser	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Least Flycatcher	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Swainson's Thrush
<input type="checkbox"/> <input type="checkbox"/> Bald Eagle	<input type="checkbox"/> <input type="checkbox"/> Common Nighthawk	<input type="checkbox"/> <input type="checkbox"/> Mallard	<input type="checkbox"/> <input type="checkbox"/> Sandhill Crane
<input type="checkbox"/> <input type="checkbox"/> Baltimore Oriole	<input type="checkbox"/> <input type="checkbox"/> Common Raven	<input type="checkbox"/> <input checked="" type="checkbox"/> Mountain Bluebird	<input type="checkbox"/> <input checked="" type="checkbox"/> Tree Swallow
<input type="checkbox"/> <input checked="" type="checkbox"/> Barn Swallow	<input type="checkbox"/> <input checked="" type="checkbox"/> Common Yellowthroat	<input type="checkbox"/> <input checked="" type="checkbox"/> Mourning Dove	<input type="checkbox"/> <input type="checkbox"/> Turkey Vulture
<input type="checkbox"/> <input type="checkbox"/> Belted Kingfisher	<input type="checkbox"/> <input type="checkbox"/> Cooper's Hawk	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Northern Flicker	<input type="checkbox"/> <input type="checkbox"/> Upland Sandpiper
<input type="checkbox"/> <input type="checkbox"/> Black-billed Cuckoo	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Dickcissel	<input type="checkbox"/> <input type="checkbox"/> Orchard Oriole	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Vesper Sparrow
<input type="checkbox"/> <input checked="" type="checkbox"/> Black-billed Magpie	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Downy Woodpecker	<input type="checkbox"/> <input type="checkbox"/> Osprey	<input type="checkbox"/> <input checked="" type="checkbox"/> Violet-green Swallow
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-capped Chickadee	<input type="checkbox"/> <input type="checkbox"/> Eastern Bluebird	<input type="checkbox"/> <input checked="" type="checkbox"/> Ovenbird	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Warbling Vireo
<input type="checkbox"/> <input checked="" type="checkbox"/> Black-and-white Warbler	<input type="checkbox"/> <input checked="" type="checkbox"/> Eastern Kingbird	<input type="checkbox"/> <input type="checkbox"/> Plumbeous Vireo	<input type="checkbox"/> <input checked="" type="checkbox"/> Western Kingbird
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-headed Grosbeak	<input type="checkbox"/> <input type="checkbox"/> Eurasian Collared-dove	<input type="checkbox"/> <input type="checkbox"/> Red-headed Woodpecker	<input type="checkbox"/> <input checked="" type="checkbox"/> Western Meadowlark
<input type="checkbox"/> <input checked="" type="checkbox"/> Blue Jay	<input type="checkbox"/> <input checked="" type="checkbox"/> European Starling	<input type="checkbox"/> <input checked="" type="checkbox"/> Red-naped Sapsucker	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Western Wood-pewee
<input type="checkbox"/> <input checked="" type="checkbox"/> Bobolink	<input type="checkbox"/> <input checked="" type="checkbox"/> Field Sparrow	<input type="checkbox"/> <input type="checkbox"/> Red Crossbill	<input type="checkbox"/> <input checked="" type="checkbox"/> White-breasted Nuthatch
<input type="checkbox"/> <input checked="" type="checkbox"/> Brewer's Blackbird	<input type="checkbox"/> <input type="checkbox"/> Franklin's Gull	<input type="checkbox"/> <input type="checkbox"/> Ring-necked Pheasant	<input type="checkbox"/> <input checked="" type="checkbox"/> White-throated Swift
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Brown-headed Cowbird	<input type="checkbox"/> <input type="checkbox"/> Grasshopper Sparrow	<input type="checkbox"/> <input type="checkbox"/> Red-tailed hawk	<input type="checkbox"/> <input type="checkbox"/> Wild Turkey
<input type="checkbox"/> <input type="checkbox"/> Brown Creeper	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Gray Catbird	<input type="checkbox"/> <input type="checkbox"/> Rock Dove	<input type="checkbox"/> <input type="checkbox"/> Wood Duck
<input type="checkbox"/> <input checked="" type="checkbox"/> Brown Thrasher	<input type="checkbox"/> <input type="checkbox"/> Great Blue Heron	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Red-winged Blackbird	<input type="checkbox"/> <input type="checkbox"/> Yellow-bellied Sapsucker
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Bullock's Oriole	<input type="checkbox"/> <input type="checkbox"/> Great Horned Owl	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Red-eyed Vireo	<input type="checkbox"/> <input type="checkbox"/> Yellow-billed Cuckoo
<input type="checkbox"/> <input type="checkbox"/> Canada Goose	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Hairy Woodpecker	<input type="checkbox"/> <input type="checkbox"/> Red-breasted Grosbeak	<input type="checkbox"/> <input checked="" type="checkbox"/> Yellow-breasted Chat
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Cedar Waxwing	<input type="checkbox"/> <input type="checkbox"/> House Finch	<input type="checkbox"/> <input type="checkbox"/> Say's Phoebe	<input type="checkbox"/> <input checked="" type="checkbox"/> Yellow-headed Blackbird
<input type="checkbox"/> <input checked="" type="checkbox"/> Chimney Swift	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> House Wren	<input type="checkbox"/> <input checked="" type="checkbox"/> Savannah Sparrow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> 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 reach, 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.

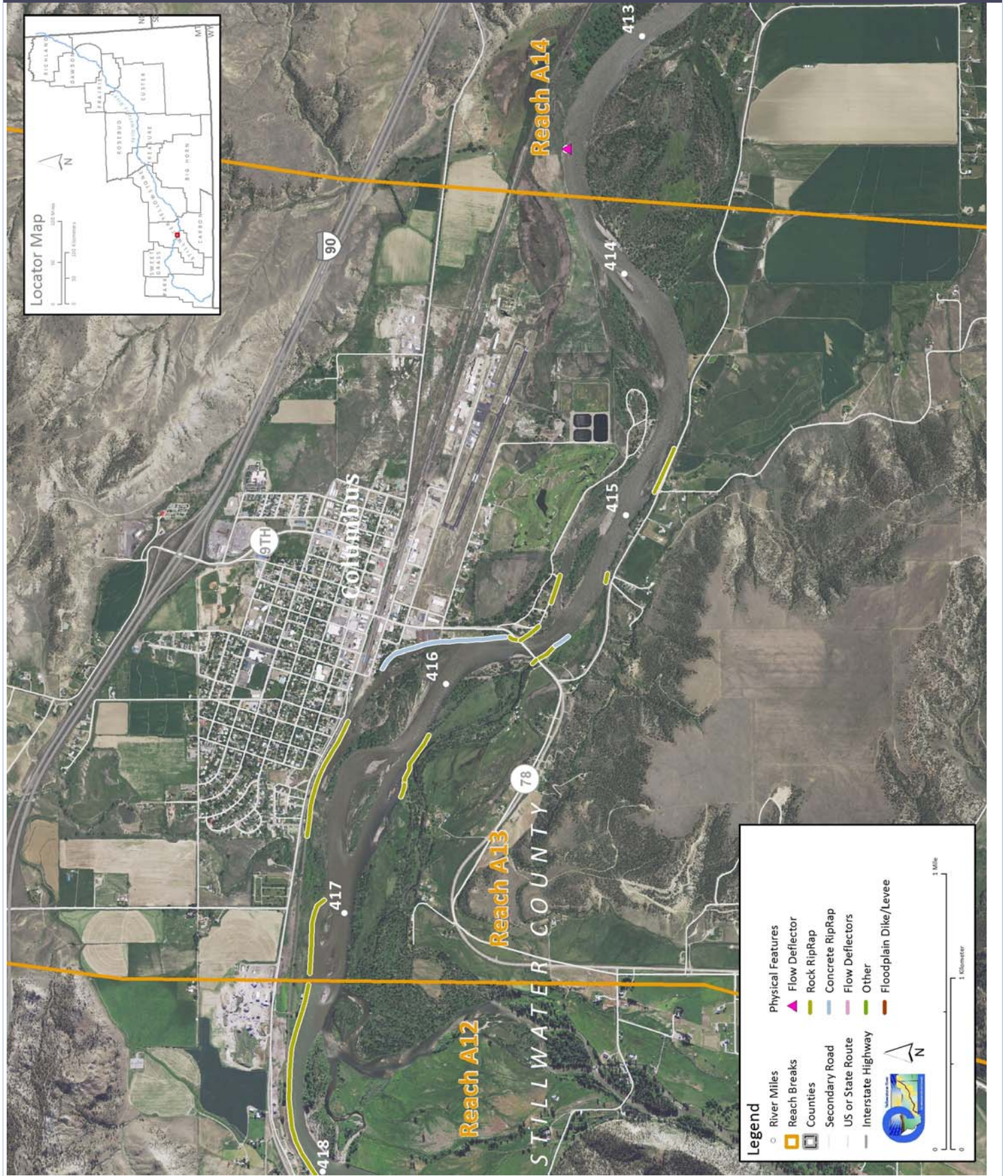
CEA-Related observations in Reach A13 include:

- 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	Gage No	Downstream Gage	Upstream Gage
1971	Jun 23	29,200	10-25 yr	6214500	6214500	6192500
1902	Jun 11	30,100	10-25 yr	Billings	Billings	Livingston
1943	Jun 20	30,600	10-25 yr	1929-2015	1929-2015	1929-2015
1974	Jun 17	36,300	50-100 yr	49.3	49.3	89.3
1996	Jun 10	37,100	50-100 yr			
1997	Jun 6	38,000	50-100 yr			
2011	Jun 30	40,600	>100-yr			

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 discrepancies 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

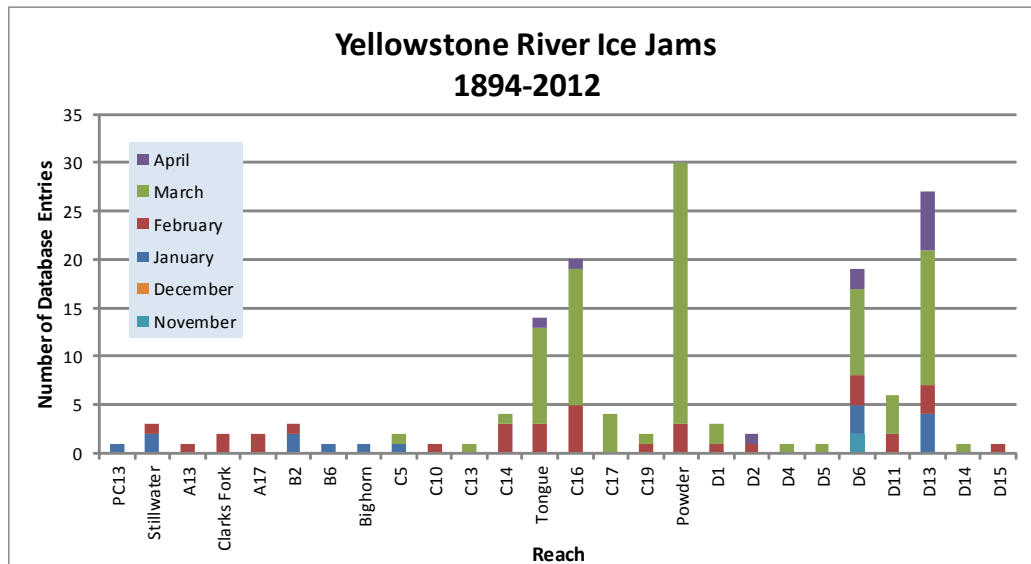
Bankline/Floodplain Inventory: Time Series

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	% Change in Braiding
1950	19,288	17,765	1.92	1950 to 1976: 4.32%
1976	18,865	18,941	2.00	1976 to 1995: 3.73%
1995	18,891	20,378	2.08	1995 to 2001: -3.21%
2001	18,980	19,208	2.01	1950 to 2001: 4.74%
Change 1950 - 2001	-308	1,443	0.09	

Length of Side Channels Blocked	Pre-1950s (ft)	Post-1950s (ft)
	0	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 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 (isolated 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 agriculture 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

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 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%

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ExUrban	Transportation
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

Feature Class	Feature Type	Acres				% of Reach Area			
		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

Feature Class	Feature Type	Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
		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

Statistic	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
	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 (YRDC) 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 developed 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 reach, 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.

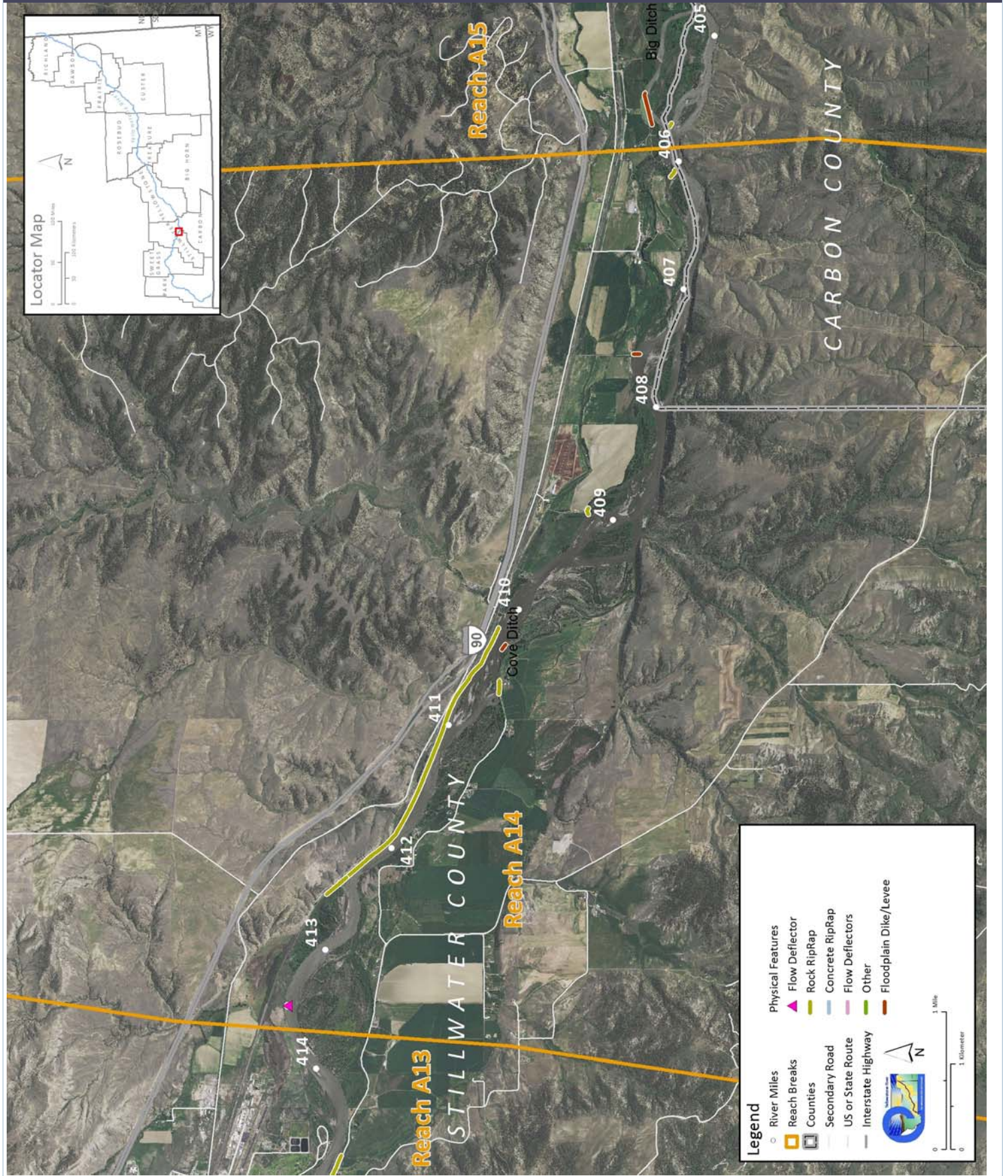
CEA-Related observations in Reach A14 include:

- 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	Gage No	Downstream Gage	Upstream Gage
1971	Jun 23	29,200	10-25 yr	6214500	6192500	
1902	Jun 11	30,100	10-25 yr	Billings	Billings	Livingston
1943	Jun 20	30,600	10-25 yr	1929-2015	1929-2015	1929-2015
1974	Jun 17	36,300	50-100 yr	Distance To (miles)	41.5	92.9
1996	Jun 10	37,100	50-100 yr			
1997	Jun 6	38,000	50-100 yr			
2011	Jun 30	40,600	>100-yr			

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 discrepancies 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

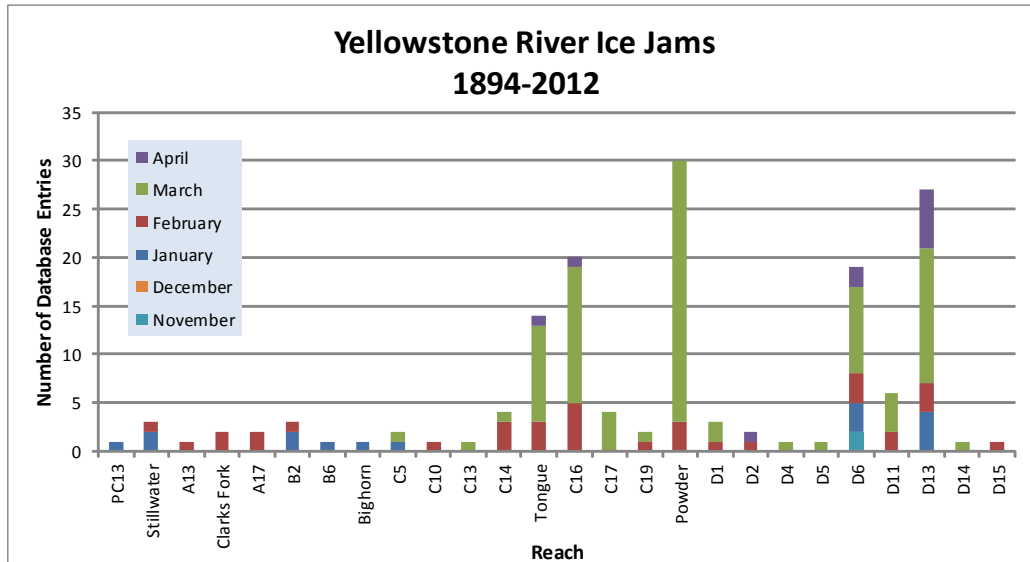
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

Feature Class	Feature Type	Sum of Feature Length (ft)					
		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 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 (isolated 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 agriculture 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	Transportation
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

Feature Class	Feature Type	Acres				% of Reach Area			
		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

Feature Class	Feature Type	Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
		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

Statistic	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
	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 (YRDC) 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 developed 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 YRDC 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
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Robin	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Chipping Sparrow	<input type="checkbox"/> <input type="checkbox"/> Killdeer	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Song Sparrow
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Crow	<input type="checkbox"/> <input checked="" type="checkbox"/> Clay-collared Sparrow	<input type="checkbox"/> <input type="checkbox"/> Lark Bunting	<input type="checkbox"/> <input type="checkbox"/> Spotted Sandpiper
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Goldfinch	<input type="checkbox"/> <input checked="" type="checkbox"/> Cliff Swallow	<input type="checkbox"/> <input checked="" type="checkbox"/> Lark Sparrow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Spotted Towhee
<input type="checkbox"/> <input type="checkbox"/> American Kestrel	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Common Grackle	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Lazuli Bunting	<input type="checkbox"/> <input type="checkbox"/> Sharp-shinned Hawk
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Redstart	<input type="checkbox"/> <input type="checkbox"/> Common Merganser	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Least Flycatcher	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Swainson's Thrush
<input type="checkbox"/> <input type="checkbox"/> Bald Eagle	<input type="checkbox"/> <input type="checkbox"/> Common Nighthawk	<input type="checkbox"/> <input type="checkbox"/> Mallard	<input type="checkbox"/> <input type="checkbox"/> Sandhill Crane
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Baltimore Oriole	<input type="checkbox"/> <input type="checkbox"/> Common Raven	<input type="checkbox"/> <input checked="" type="checkbox"/> Mountain Bluebird	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Tree Swallow
<input type="checkbox"/> <input checked="" type="checkbox"/> Barn Swallow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Common Yellowthroat	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Mourning Dove	<input type="checkbox"/> <input type="checkbox"/> Turkey Vulture
<input type="checkbox"/> <input type="checkbox"/> Belted Kingfisher	<input type="checkbox"/> <input type="checkbox"/> Cooper's Hawk	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Northern Flicker	<input type="checkbox"/> <input type="checkbox"/> Upland Sandpiper
<input type="checkbox"/> <input type="checkbox"/> Black-billed Cuckoo	<input type="checkbox"/> <input checked="" type="checkbox"/> Dickcissel	<input type="checkbox"/> <input type="checkbox"/> Orchard Oriole	<input type="checkbox"/> <input checked="" type="checkbox"/> Vesper Sparrow
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-billed Magpie	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Downy Woodpecker	<input type="checkbox"/> <input type="checkbox"/> Osprey	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Violet-green Swallow
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-capped Chickadee	<input type="checkbox"/> <input type="checkbox"/> Eastern Bluebird	<input type="checkbox"/> <input checked="" type="checkbox"/> Ovenbird	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Warbling Vireo
<input type="checkbox"/> <input checked="" type="checkbox"/> Black-and-white Warbler	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Eastern Kingbird	<input type="checkbox"/> <input type="checkbox"/> Plumbeous Vireo	<input type="checkbox"/> <input checked="" type="checkbox"/> Western Kingbird
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-headed Grosbeak	<input type="checkbox"/> <input type="checkbox"/> Eurasian Collared-dove	<input type="checkbox"/> <input type="checkbox"/> Red-headed Woodpecker	<input type="checkbox"/> <input checked="" type="checkbox"/> Western Meadowlark
<input type="checkbox"/> <input checked="" type="checkbox"/> Blue Jay	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> European Starling	<input type="checkbox"/> <input checked="" type="checkbox"/> Red-naped Sapsucker	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Western Wood-pewee
<input type="checkbox"/> <input checked="" type="checkbox"/> Bobolink	<input type="checkbox"/> <input checked="" type="checkbox"/> Field Sparrow	<input type="checkbox"/> <input type="checkbox"/> Red Crossbill	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> White-breasted Nuthatch
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Brewer's Blackbird	<input type="checkbox"/> <input type="checkbox"/> Franklin's Gull	<input type="checkbox"/> <input type="checkbox"/> Ring-necked Pheasant	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> White-throated Swift
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Brown-headed Cowbird	<input type="checkbox"/> <input type="checkbox"/> Grasshopper Sparrow	<input type="checkbox"/> <input type="checkbox"/> Red-tailed hawk	<input type="checkbox"/> <input type="checkbox"/> Wild Turkey
<input type="checkbox"/> <input type="checkbox"/> Brown Creeper	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Gray Catbird	<input type="checkbox"/> <input type="checkbox"/> Rock Dove	<input type="checkbox"/> <input type="checkbox"/> Wood Duck
<input type="checkbox"/> <input checked="" type="checkbox"/> Brown Thrasher	<input type="checkbox"/> <input type="checkbox"/> Great Blue Heron	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Red-winged Blackbird	<input type="checkbox"/> <input type="checkbox"/> Yellow-bellied Sapsucker
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Bullock's Oriole	<input type="checkbox"/> <input type="checkbox"/> Great Horned Owl	<input type="checkbox"/> <input checked="" type="checkbox"/> Red-eyed Vireo	<input type="checkbox"/> <input type="checkbox"/> Yellow-billed Cuckoo
<input type="checkbox"/> <input type="checkbox"/> Canada Goose	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Hairy Woodpecker	<input type="checkbox"/> <input type="checkbox"/> Red-breasted Grosbeak	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Yellow-breasted Chat
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Cedar Waxwing	<input type="checkbox"/> <input type="checkbox"/> House Finch	<input type="checkbox"/> <input type="checkbox"/> Say's Phoebe	<input type="checkbox"/> <input checked="" type="checkbox"/> Yellow-headed Blackbird
<input type="checkbox"/> <input checked="" type="checkbox"/> Chimney Swift	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> House Wren	<input type="checkbox"/> <input checked="" type="checkbox"/> Savannah Sparrow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> 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 reach, 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.

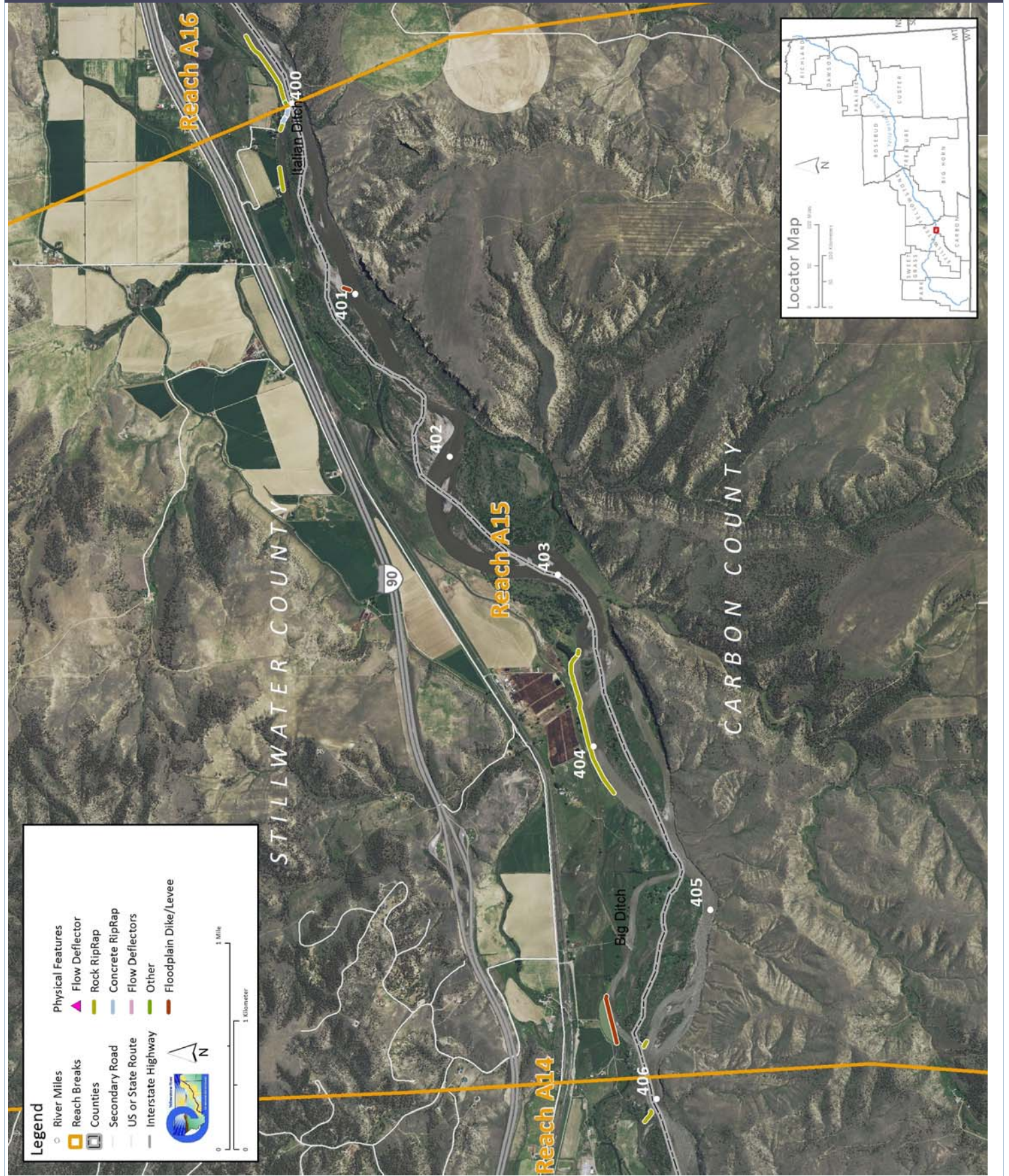
CEA-Related observations in Reach A15 include:

- 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	Gage No	Downstream Gage	Upstream Gage
1971	Jun 23	29,200	10-25 yr	6214500	6214500	6192500
1902	Jun 11	30,100	10-25 yr	Billings	Billings	Livingston
1943	Jun 20	30,600	10-25 yr	1929-2015	1929-2015	1929-2015
1974	Jun 17	36,300	50-100 yr	35.6	35.6	100.7
1996	Jun 10	37,100	50-100 yr			
1997	Jun 6	38,000	50-100 yr			
2011	Jun 30	40,600	>100-yr			

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 discrepancies 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.

Feature Class	Feature Type	Sum of Feature Length (ft)					
		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

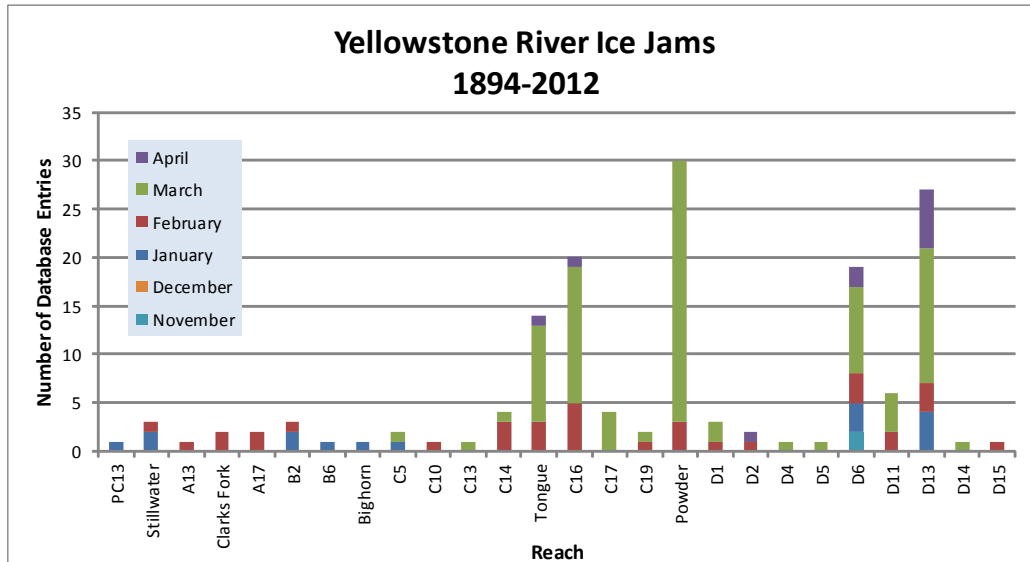
1,031 1,031 1,031 1,031 1,031 1,031

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 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 (isolated 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 agriculture 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	Transportation
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

Feature Class	Feature Type	Acres				% of Reach Area			
		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

Feature Class	Feature Type	Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
		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

Statistic	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
	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 (YRCD) 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 developed 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	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.

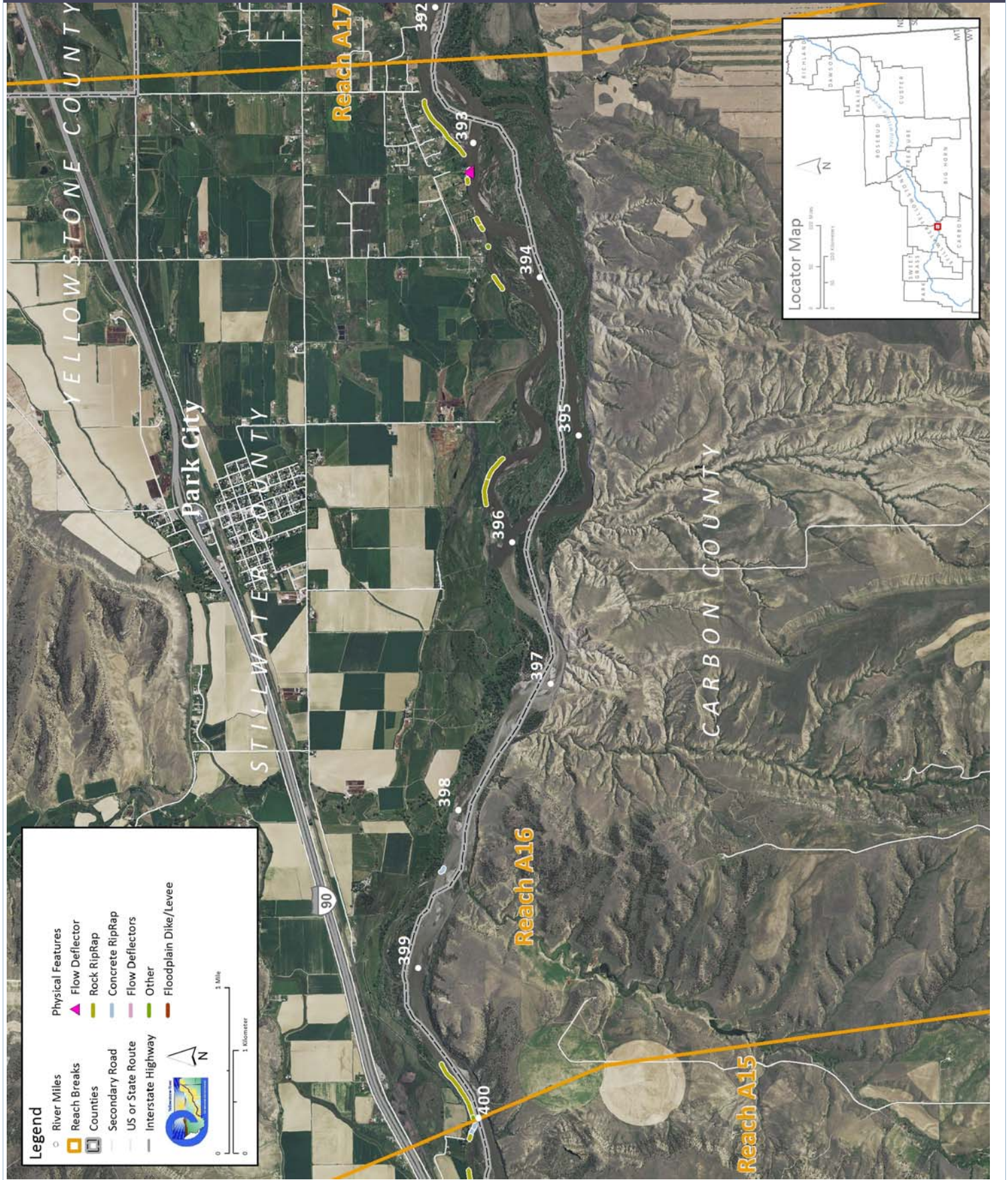
CEA-Related observations in Reach A16 include:

- 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	Gage No	Downstream Gage	Upstream Gage
1971	Jun 23	29,200	10-25 yr	6214500	6192500	
1902	Jun 11	30,100	10-25 yr	Billings	Billings	Livingston
1943	Jun 20	30,600	10-25 yr	1929-2015	1929-2015	1929-2015
1974	Jun 17	36,300	50-100 yr	28.0	28.0	106.6
1996	Jun 10	37,100	50-100 yr			
1997	Jun 6	38,000	50-100 yr			
2011	Jun 30	40,600	>100-yr			

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 discrepancies 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

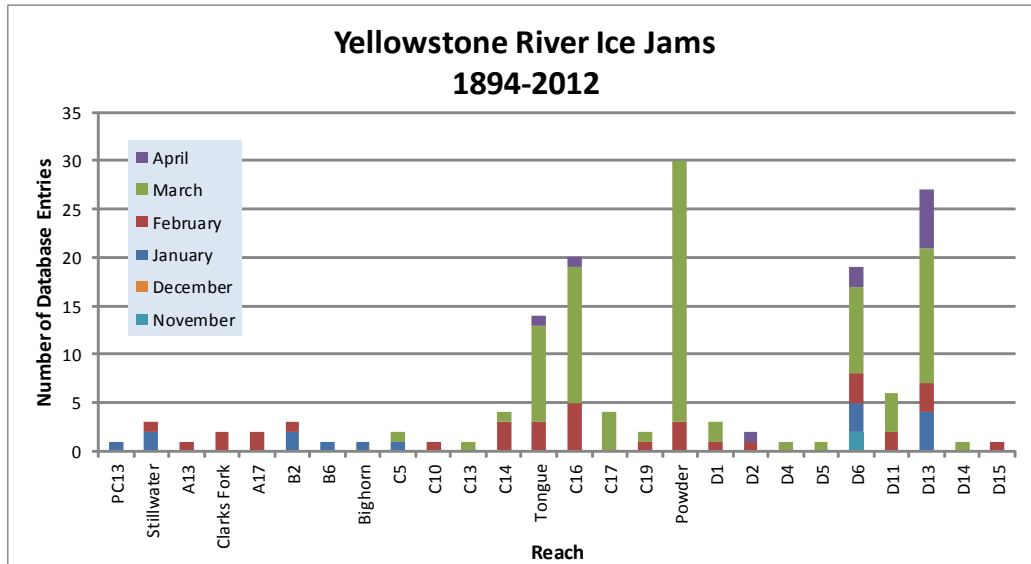
Bankline/Floodplain Inventory: Time Series

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 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 (isolated 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 agriculture 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	Transportation
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

Feature Class	Feature Type	Acres				% of Reach Area			
		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

Feature Class	Feature Type	Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
		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

Statistic	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
	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 (YRCD) 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 developed 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	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
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Robin	<input type="checkbox"/> <input checked="" type="checkbox"/> Chipping Sparrow	<input type="checkbox"/> <input type="checkbox"/> Killdeer	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Song Sparrow
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Crow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Clay-collared Sparrow	<input type="checkbox"/> <input type="checkbox"/> Lark Bunting	<input type="checkbox"/> <input type="checkbox"/> Spotted Sandpiper
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Goldfinch	<input type="checkbox"/> <input checked="" type="checkbox"/> Cliff Swallow	<input type="checkbox"/> <input checked="" type="checkbox"/> Lark Sparrow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Spotted Towhee
<input type="checkbox"/> <input type="checkbox"/> American Kestrel	<input type="checkbox"/> <input checked="" type="checkbox"/> Common Grackle	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Lazuli Bunting	<input type="checkbox"/> <input type="checkbox"/> Sharp-shinned Hawk
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Redstart	<input type="checkbox"/> <input type="checkbox"/> Common Merganser	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Least Flycatcher	<input type="checkbox"/> <input checked="" type="checkbox"/> Swainson's Thrush
<input type="checkbox"/> <input type="checkbox"/> Bald Eagle	<input type="checkbox"/> <input type="checkbox"/> Common Nighthawk	<input type="checkbox"/> <input type="checkbox"/> Mallard	<input type="checkbox"/> <input type="checkbox"/> Sandhill Crane
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Baltimore Oriole	<input type="checkbox"/> <input type="checkbox"/> Common Raven	<input type="checkbox"/> <input checked="" type="checkbox"/> Mountain Bluebird	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Tree Swallow
<input type="checkbox"/> <input checked="" type="checkbox"/> Barn Swallow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Common Yellowthroat	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Mourning Dove	<input type="checkbox"/> <input type="checkbox"/> Turkey Vulture
<input type="checkbox"/> <input type="checkbox"/> Belted Kingfisher	<input type="checkbox"/> <input type="checkbox"/> Cooper's Hawk	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Northern Flicker	<input type="checkbox"/> <input type="checkbox"/> Upland Sandpiper
<input type="checkbox"/> <input type="checkbox"/> Black-billed Cuckoo	<input type="checkbox"/> <input checked="" type="checkbox"/> Dickcissel	<input type="checkbox"/> <input type="checkbox"/> Orchard Oriole	<input type="checkbox"/> <input checked="" type="checkbox"/> Vesper Sparrow
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-billed Magpie	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Downy Woodpecker	<input type="checkbox"/> <input type="checkbox"/> Osprey	<input type="checkbox"/> <input checked="" type="checkbox"/> Violet-green Swallow
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-capped Chickadee	<input type="checkbox"/> <input type="checkbox"/> Eastern Bluebird	<input type="checkbox"/> <input checked="" type="checkbox"/> Ovenbird	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Warbling Vireo
<input type="checkbox"/> <input checked="" type="checkbox"/> Black-and-white Warbler	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Eastern Kingbird	<input type="checkbox"/> <input type="checkbox"/> Plumbeous Vireo	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Western Kingbird
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-headed Grosbeak	<input type="checkbox"/> <input type="checkbox"/> Eurasian Collared-dove	<input type="checkbox"/> <input type="checkbox"/> Red-headed Woodpecker	<input type="checkbox"/> <input checked="" type="checkbox"/> Western Meadowlark
<input type="checkbox"/> <input checked="" type="checkbox"/> Blue Jay	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> European Starling	<input type="checkbox"/> <input checked="" type="checkbox"/> Red-naped Sapsucker	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Western Wood-pewee
<input type="checkbox"/> <input checked="" type="checkbox"/> Bobolink	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Field Sparrow	<input type="checkbox"/> <input type="checkbox"/> Red Crossbill	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> White-breasted Nuthatch
<input type="checkbox"/> <input checked="" type="checkbox"/> Brewer's Blackbird	<input type="checkbox"/> <input type="checkbox"/> Franklin's Gull	<input type="checkbox"/> <input type="checkbox"/> Ring-necked Pheasant	<input type="checkbox"/> <input checked="" type="checkbox"/> White-throated Swift
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Brown-headed Cowbird	<input type="checkbox"/> <input type="checkbox"/> Grasshopper Sparrow	<input type="checkbox"/> <input type="checkbox"/> Red-tailed hawk	<input type="checkbox"/> <input type="checkbox"/> Wild Turkey
<input type="checkbox"/> <input type="checkbox"/> Brown Creeper	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Gray Catbird	<input type="checkbox"/> <input type="checkbox"/> Rock Dove	<input type="checkbox"/> <input type="checkbox"/> Wood Duck
<input type="checkbox"/> <input checked="" type="checkbox"/> Brown Thrasher	<input type="checkbox"/> <input type="checkbox"/> Great Blue Heron	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Red-winged Blackbird	<input type="checkbox"/> <input type="checkbox"/> Yellow-bellied Sapsucker
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Bullock's Oriole	<input type="checkbox"/> <input type="checkbox"/> Great Horned Owl	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Red-eyed Vireo	<input type="checkbox"/> <input type="checkbox"/> Yellow-billed Cuckoo
<input type="checkbox"/> <input type="checkbox"/> Canada Goose	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Hairy Woodpecker	<input type="checkbox"/> <input type="checkbox"/> Red-breasted Grosbeak	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Yellow-breasted Chat
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Cedar Waxwing	<input type="checkbox"/> <input type="checkbox"/> House Finch	<input type="checkbox"/> <input type="checkbox"/> Say's Phoebe	<input type="checkbox"/> <input checked="" type="checkbox"/> Yellow-headed Blackbird
<input type="checkbox"/> <input checked="" type="checkbox"/> Chimney Swift	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> House Wren	<input type="checkbox"/> <input checked="" type="checkbox"/> Savannah Sparrow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> 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 lost, 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:

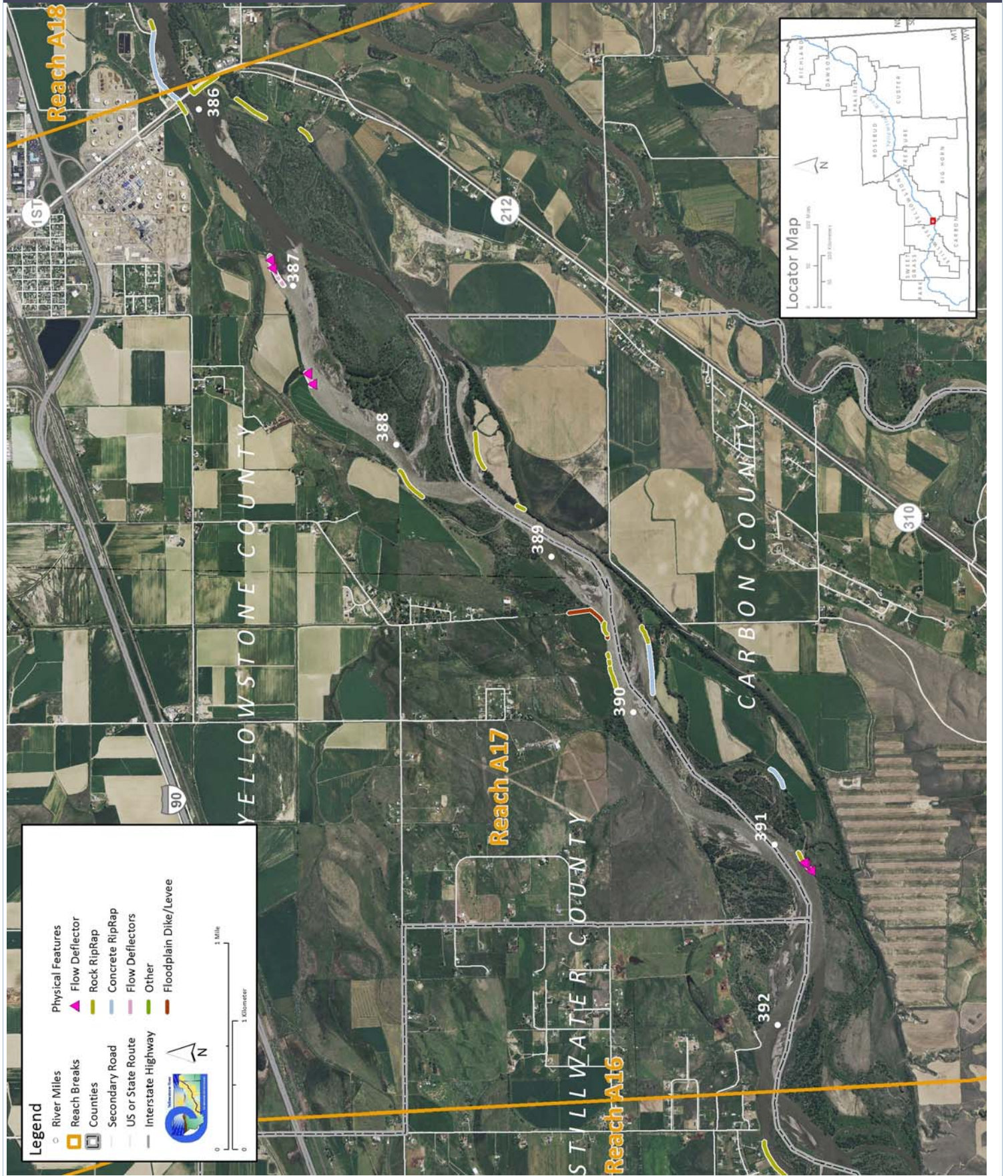
- Flanking of flow deflectors and accelerated erosion behind flanked structures

- 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	Gage No	Downstream Gage	Upstream Gage
1971	Jun 23	29,200	10-25 yr		6214500	6192500
1902	Jun 11	30,100	10-25 yr		Billings	Livingston
1943	Jun 20	30,600	10-25 yr		1929-2015	1929-2015
1974	Jun 17	36,300	50-100 yr		Distance To (miles)	21.6
1996	Jun 10	37,100	50-100 yr			114.2
1997	Jun 6	38,000	50-100 yr			
2011	Jun 30	40,600	>100-yr			

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 discrepancies 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

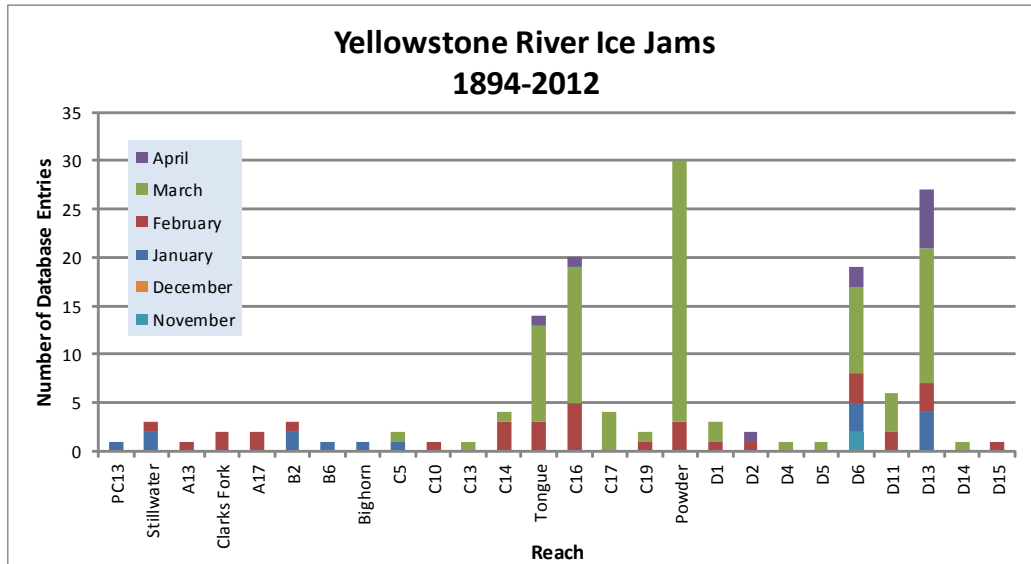
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

Feature Class	Feature Type	Sum of Feature Length (ft)					
		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	% Change in Braiding
1950	34,729	37,999	2.09	1950 to 1976: 1.44%
1976	34,084	38,322	2.12	1976 to 1995: -12.94%
1995	34,298	29,134	1.85	1995 to 2001: 3.76%
2001	34,137	31,373	1.92	1950 to 2001: -8.36%
Change 1950 - 2001	-592	-6,626	-0.18	

Length of Side Channels Blocked	Pre-1950s (ft)	Post-1950s (ft)
	7,639	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 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 (isolated 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 agriculture 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	Transportation
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

Feature Class	Feature Type	Acres				% of Reach Area			
		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

Feature Class	Feature Type	Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
		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

Statistic	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
	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 (YRCD) 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 developed 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	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
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Robin	<input type="checkbox"/> <input checked="" type="checkbox"/> Chipping Sparrow	<input type="checkbox"/> <input type="checkbox"/> Killdeer	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Song Sparrow
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Crow	<input type="checkbox"/> <input checked="" type="checkbox"/> Clay-collared Sparrow	<input type="checkbox"/> <input type="checkbox"/> Lark Bunting	<input type="checkbox"/> <input type="checkbox"/> Spotted Sandpiper
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Goldfinch	<input type="checkbox"/> <input checked="" type="checkbox"/> Cliff Swallow	<input type="checkbox"/> <input checked="" type="checkbox"/> Lark Sparrow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Spotted Towhee
<input type="checkbox"/> <input type="checkbox"/> American Kestrel	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Common Grackle	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Lazuli Bunting	<input type="checkbox"/> <input type="checkbox"/> Sharp-shinned Hawk
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> American Redstart	<input type="checkbox"/> <input type="checkbox"/> Common Merganser	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Least Flycatcher	<input type="checkbox"/> <input checked="" type="checkbox"/> Swainson's Thrush
<input type="checkbox"/> <input type="checkbox"/> Bald Eagle	<input type="checkbox"/> <input type="checkbox"/> Common Nighthawk	<input type="checkbox"/> <input type="checkbox"/> Mallard	<input type="checkbox"/> <input type="checkbox"/> Sandhill Crane
<input type="checkbox"/> <input type="checkbox"/> Baltimore Oriole	<input type="checkbox"/> <input type="checkbox"/> Common Raven	<input type="checkbox"/> <input checked="" type="checkbox"/> Mountain Bluebird	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Tree Swallow
<input type="checkbox"/> <input checked="" type="checkbox"/> Barn Swallow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Common Yellowthroat	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Mourning Dove	<input type="checkbox"/> <input type="checkbox"/> Turkey Vulture
<input type="checkbox"/> <input type="checkbox"/> Belted Kingfisher	<input type="checkbox"/> <input type="checkbox"/> Cooper's Hawk	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Northern Flicker	<input type="checkbox"/> <input type="checkbox"/> Upland Sandpiper
<input type="checkbox"/> <input type="checkbox"/> Black-billed Cuckoo	<input type="checkbox"/> <input checked="" type="checkbox"/> Dickcissel	<input type="checkbox"/> <input type="checkbox"/> Orchard Oriole	<input type="checkbox"/> <input checked="" type="checkbox"/> Vesper Sparrow
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-billed Magpie	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Downy Woodpecker	<input type="checkbox"/> <input type="checkbox"/> Osprey	<input type="checkbox"/> <input checked="" type="checkbox"/> Violet-green Swallow
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-capped Chickadee	<input type="checkbox"/> <input type="checkbox"/> Eastern Bluebird	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Ovenbird	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Warbling Vireo
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-and-white Warbler	<input type="checkbox"/> <input checked="" type="checkbox"/> Eastern Kingbird	<input type="checkbox"/> <input type="checkbox"/> Plumbeous Vireo	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Western Kingbird
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Black-headed Grosbeak	<input type="checkbox"/> <input type="checkbox"/> Eurasian Collared-dove	<input type="checkbox"/> <input type="checkbox"/> Red-headed Woodpecker	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Western Meadowlark
<input type="checkbox"/> <input checked="" type="checkbox"/> Blue Jay	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> European Starling	<input type="checkbox"/> <input checked="" type="checkbox"/> Red-naped Sapsucker	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Western Wood-pewee
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Bobolink	<input type="checkbox"/> <input checked="" type="checkbox"/> Field Sparrow	<input type="checkbox"/> <input type="checkbox"/> Red Crossbill	<input type="checkbox"/> <input checked="" type="checkbox"/> White-breasted Nuthatch
<input type="checkbox"/> <input checked="" type="checkbox"/> Brewer's Blackbird	<input type="checkbox"/> <input type="checkbox"/> Franklin's Gull	<input type="checkbox"/> <input type="checkbox"/> Ring-necked Pheasant	<input type="checkbox"/> <input checked="" type="checkbox"/> White-throated Swift
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Brown-headed Cowbird	<input type="checkbox"/> <input type="checkbox"/> Grasshopper Sparrow	<input type="checkbox"/> <input type="checkbox"/> Red-tailed hawk	<input type="checkbox"/> <input type="checkbox"/> Wild Turkey
<input type="checkbox"/> <input type="checkbox"/> Brown Creeper	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Gray Catbird	<input type="checkbox"/> <input type="checkbox"/> Rock Dove	<input type="checkbox"/> <input type="checkbox"/> Wood Duck
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Brown Thrasher	<input type="checkbox"/> <input type="checkbox"/> Great Blue Heron	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Red-winged Blackbird	<input type="checkbox"/> <input type="checkbox"/> Yellow-bellied Sapsucker
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Bullock's Oriole	<input type="checkbox"/> <input type="checkbox"/> Great Horned Owl	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Red-eyed Vireo	<input type="checkbox"/> <input type="checkbox"/> Yellow-billed Cuckoo
<input type="checkbox"/> <input type="checkbox"/> Canada Goose	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Hairy Woodpecker	<input type="checkbox"/> <input type="checkbox"/> Red-breasted Grosbeak	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Yellow-breasted Chat
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Cedar Waxwing	<input type="checkbox"/> <input type="checkbox"/> House Finch	<input type="checkbox"/> <input type="checkbox"/> Say's Phoebe	<input type="checkbox"/> <input checked="" type="checkbox"/> Yellow-headed Blackbird
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Chimney Swift	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> House Wren	<input type="checkbox"/> <input checked="" type="checkbox"/> Savannah Sparrow	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> 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.