County	Park	**Upstream River Mile**	495.6
Classification	PCB: Partially confined braided	**Downstream River Mile**	493.6
General Location	Through Hwy 89 bridge crossing to Shields River	**Length**	2.00 mi (3.22 km)

General Comments

Narrative Summary

Reach PC17 is 2.0 miles long, extending from just above the Highway 89 Bridge to just below the mouth of the Shields River. The reach is highly impacted by the two bridges that cross the river in the middle of the reach. One is the Highway 89 Bridge and the other is an abandoned railroad bridge that runs parallel to it just upstream.

There is over a mile of bank armor in Reach PC17, about 5,700 feet of which is rock riprap and another 130 feet is flow deflectors. About 28 percent of the total bankline, including those of side channels, is armored. Most of the armor is associated with the bridges.

About 25 percent of the Channel Migration Zone in Reach PC17 has been restricted by physical features. Much of this restriction takes place near the upper end of the reach, where the Highway 89 Bridge has restricted the natural CMZ from a width of 1800 feet down to 300 feet, isolating about 90 acres of ground downstream of the bridge approach. This constriction at the bridge has also caused extensive deposition upstream, and as a result the river currently flows parallel to the highway before “doglegging” through the bridge opening.

There are also 7,300 feet of mapped floodplain dikes in the reach. These dikes are all associated with the transportation prisms at the bridges. Construction of the bridges also resulted in the blockage of about 3,950 feet of side channel prior to 1950 on the north floodplain just downstream.

Land uses in Reach PC17 are almost entirely agricultural, with historic flood irrigation converting to sprinkler and pivot, and some exurban development. The major land use in the reach, however, is non-irrigated agriculture.

About 85 acres of wetlands have been mapped in Reach PC17, most of which are emergent marshes and wet meadows. Most of these wetlands are in non-irrigated hay pastures or multi-use riparian bottoms.

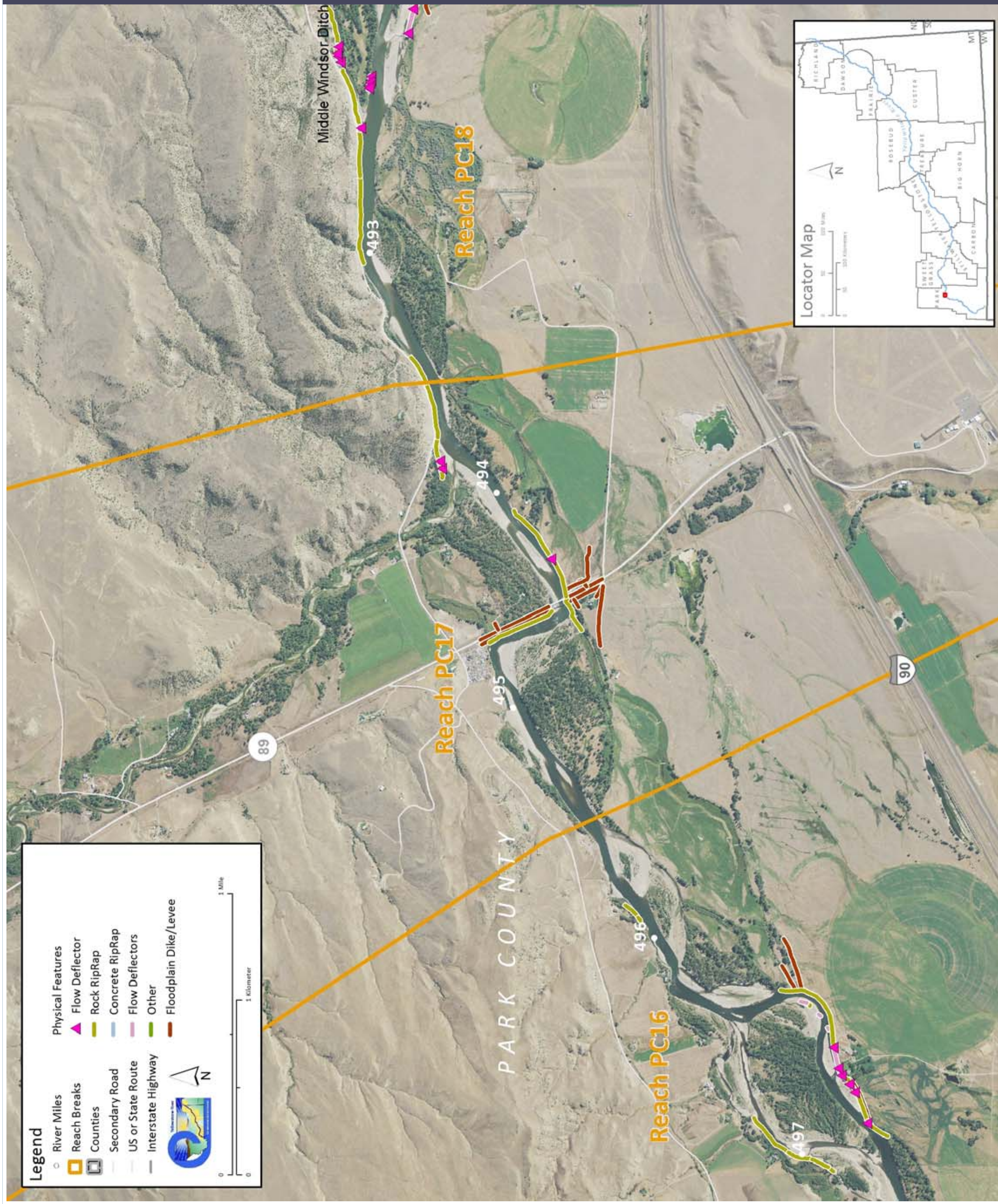
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011,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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,720 cfs to 1,560 cfs with human development, a reduction of 9.3 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC17 include:
•Constriction of CMZ at bridge and poor river alignment to structure.
•Side channel blockage by transportation embankment.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC17 include:
•Floodplain restoration/connectivity below transportation embankment at RM 494.5
•Side channel restoration below transportation embankment at RM 494.5
•CMZ Management due to current restriction of 25 percent of the Channel Migration Zone
•Bank Stabilization Recommended Practices due to the extent of armoring in the reach (28 percent armored banks)

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	129.2	11.0

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	10,400	20,600	25,900	29,200	35,900	38,700	44,900	1,720	1,760
Regulated	10,300	20,500	25,800	29,100	35,800	38,600	44,800	1,560	1,680
% Change	-0.96%	-0.49%	-0.39%	-0.34%	-0.28%	-0.26%	-0.22%	-9.30%	-4.55%

AERIAL PHOTOGRAPHY

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

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

PHYSICAL FEATURES

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

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

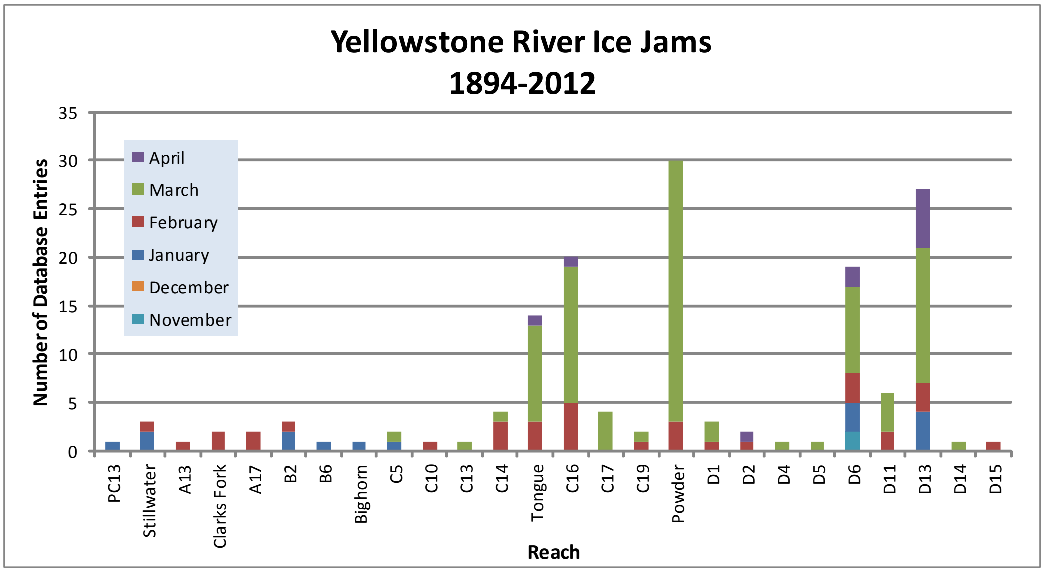
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	5,760	27.6%	5,704	27.3%	-56
	Flow Deflectors	78	0.4%	134	0.6%	56
	Feature Type Totals	**5,838**	**28.0%**	**5,838**	**28.0%**	**0**
Floodplain Control						
	Floodplain Dike/Levee	7,290	34.9%	7,290	34.9%	0
	Feature Type Totals	**7,290**	**34.9%**	**7,290**	**34.9%**	**0**
	Reach Totals	**13,128**	**62.9%**	**13,128**	**62.9%**	**0**

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	10,030	2,384	1.24	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	10,430	2,345	1.22	1950 to 2001:	-1.04%
Change 1950 - 2001	**400**	**-39**	**-0.01**		

Length of Side Channels Blocked

Pre-1950s (ft)	3,948
Post-1950s (ft)	0

HYDRAULICS

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

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

Floodplain Isolation

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

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
112	223	209	25	12%	213	81	38%

2011 Restricted Migration Area Summary

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

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Non-Irrigated	90	21.2%
RipRap/Flow Deflectors			
	Public Road	2	0.4%
RipRap			
	Railroad	4	1.0%
	Non-Irrigated	10	2.4%
	Totals	**106**	**25.1%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
18.3	0.0	0.0	4.8	2.3

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	11	31	38	44	1.1%	3.2%	3.9%	4.5%
	Totals	**11**	**31**	**38**	**44**	**1.1%**	**3.2%**	**3.9%**	**4.5%**
Agricultural Land									
	Non-Irrigated	462	521	493	611	47.6%	53.6%	50.8%	62.9%
	Irrigated	384	255	255	125	39.5%	26.3%	26.2%	12.9%
	Totals	**846**	**776**	**748**	**736**	**87.1%**	**79.8%**	**77.0%**	**75.8%**
Channel									
	Channel	96	126	131	132	9.9%	13.0%	13.5%	13.6%
	Totals	**96**	**126**	**131**	**132**	**9.9%**	**13.0%**	**13.5%**	**13.6%**
ExUrban									
	ExUrban Other	0	9	10	10	0.0%	1.0%	1.0%	1.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	8	8	8	0.0%	0.8%	0.8%	0.8%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	1	17	22	0.0%	0.1%	1.8%	2.2%
	Totals	**0**	**19**	**35**	**40**	**0.0%**	**1.9%**	**3.6%**	**4.1%**
Transportation									
	Public Road	11	20	20	20	1.2%	2.1%	2.1%	2.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	7	0	0	0	0.7%	0.0%	0.0%	0.0%
	Totals	**18**	**20**	**20**	**20**	**1.9%**	**2.1%**	**2.1%**	**2.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	40	60	0.0%	0.0%	5.4%	8.2%	0.0%	5.4%	2.9%	8.2%
	Pivot	0	0	0	47	0.0%	0.0%	0.0%	6.3%	0.0%	0.0%	6.3%	6.3%
	Flood	384	255	215	18	45.4%	32.9%	28.7%	2.5%	-12.5%	-4.2%	-26.2%	-42.9%
	Totals	**384**	**255**	**255**	**125**	**45.4%**	**32.9%**	**34.1%**	**17.0%**	**-12.5%**	**1.2%**	**-17.0%**	**-28.3%**

Non-Irrigated

Multi-Use	441	446	463	478	52.1%	57.4%	61.9%	64.9%	5.3%	4.5%	3.0%	12.8%
Hay/Pasture	21	75	30	133	2.5%	9.7%	4.0%	18.1%	7.1%	-5.7%	14.0%	15.5%
Totals	**462**	**521**	**493**	**611**	**54.6%**	**67.1%**	**65.9%**	**83.0%**	**12.5%**	**-1.2%**	**17.0%**	**28.3%**

RIPARIAN

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

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

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	2.0	65.1	19.0	0.0	**86.1**
Acres/Valley Mile	1.2	37.9	11.0	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.27	0.07%	0.09	0.01	0.00	0.00

FISHERIES SUMMARY

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

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

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

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

AVIAN

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