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

General Comments

Narrative Summary

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

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

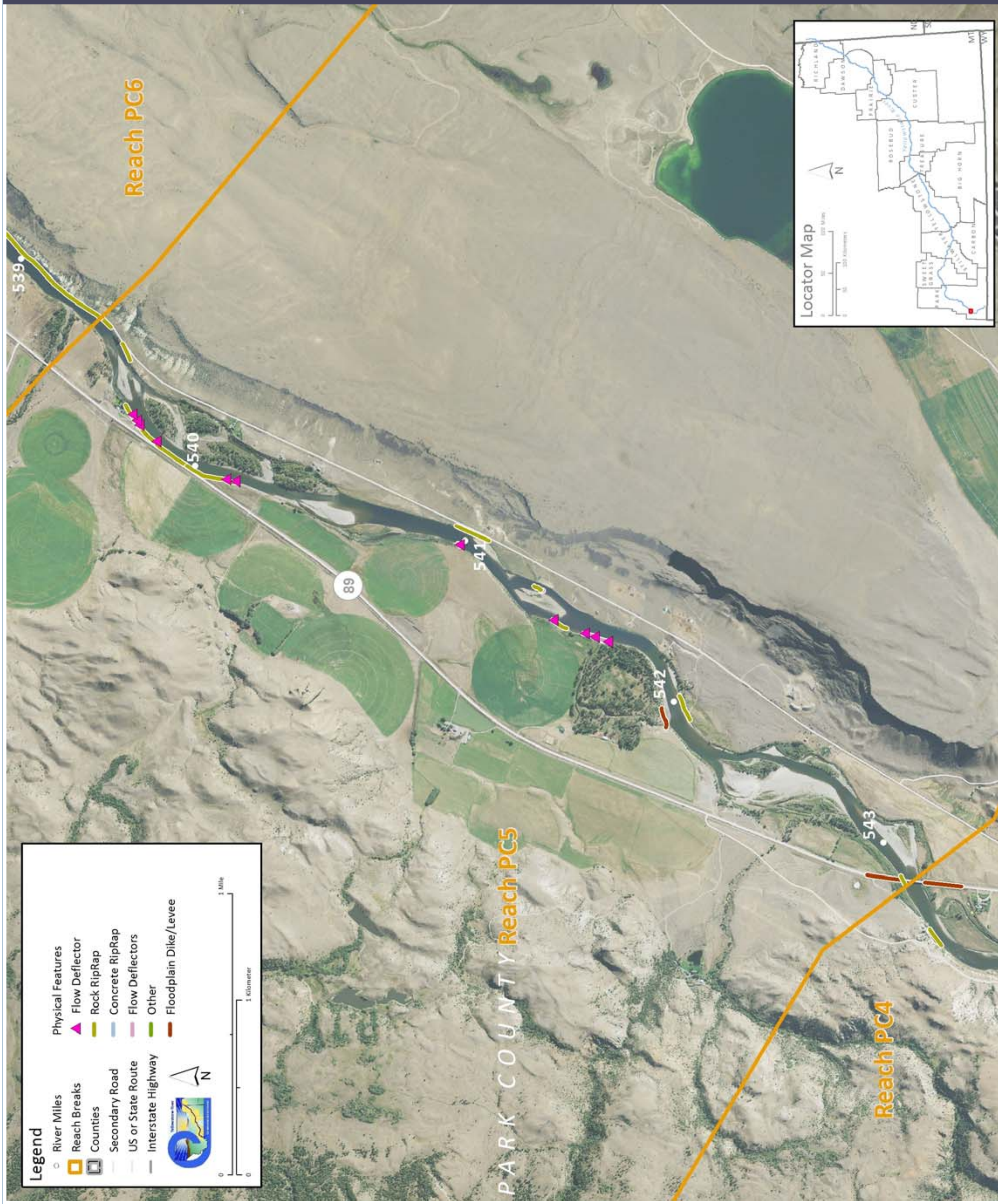
The influence of irrigation on streamflow is small but evident in Reach PC5. When gage data are extrapolated to reaches based on drainage area, Reach PC5 shows a 100 cfs reduction in the 2-year flood under developed conditions. This is a 0.5 percent reduction in the total flow of 19,000 cfs.

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

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

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

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Corwin Springs

Flood History

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

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

Discharge

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

AERIAL PHOTOGRAPHY

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

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

PHYSICAL FEATURES

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

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

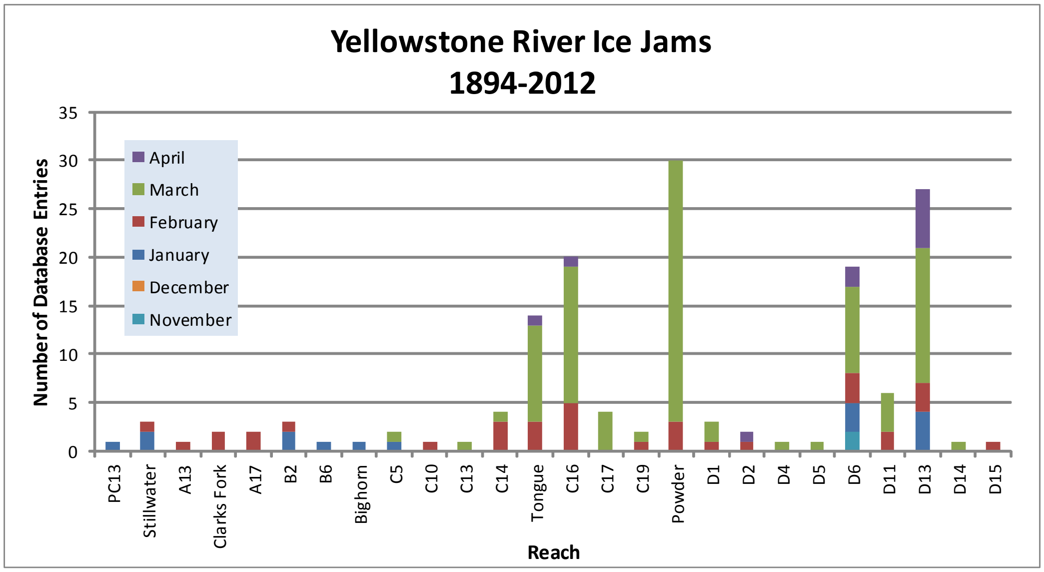
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

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

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

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

Length of Side Channels Blocked

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

HYDRAULICS

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

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

Floodplain Isolation

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

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

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

CHANNEL MIGRATION ZONE

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

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

2011 Restricted Migration Area Summary

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

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

Land Uses within the CMZ (Acres)

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

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

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

Land Use Timeline - Tiers 3 and 4

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

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

RIPARIAN

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

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

WETLANDS

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

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

RUSSIAN OLIVE

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

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

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

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

FISHERIES SUMMARY

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

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

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

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

AVIAN

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