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

General Comments

Narrative Summary

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

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

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

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

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

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

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

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

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

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

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

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

Discharge

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

AERIAL PHOTOGRAPHY

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

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

PHYSICAL FEATURES

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

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

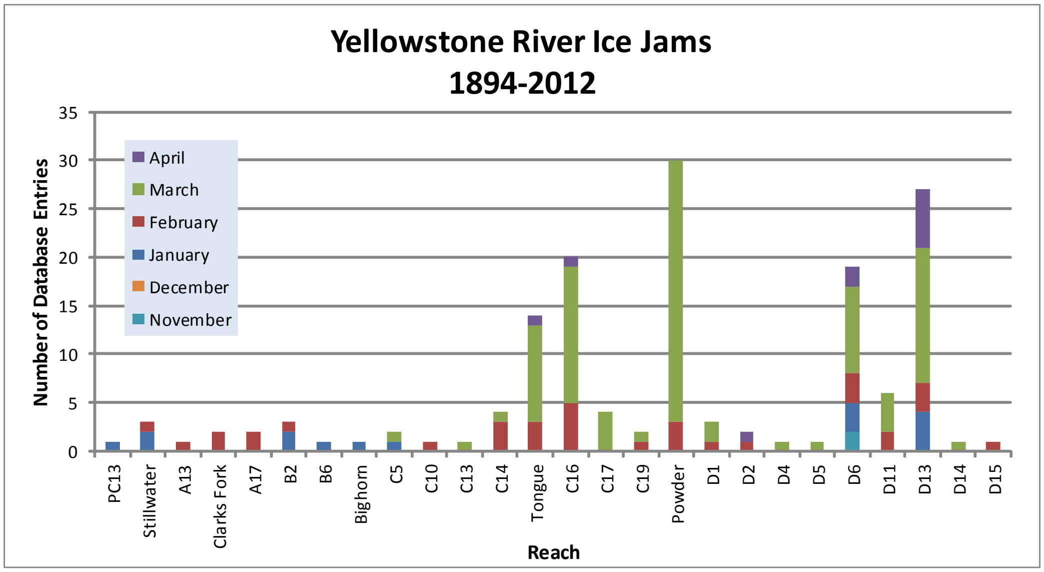
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

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

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

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

Length of Side Channels Blocked

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

HYDRAULICS

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

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

Floodplain Isolation

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

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

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

CHANNEL MIGRATION ZONE

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

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

2011 Restricted Migration Area Summary

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

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

Land Uses within the CMZ (Acres)

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

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

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

Land Use Timeline - Tiers 3 and 4

		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	89	102	0.0%	0.0%	10.3%	10.9%	0.0%	10.3%	0.6%	10.9%
	Pivot	0	0	25	80	0.0%	0.0%	2.9%	8.5%	0.0%	2.9%	5.6%	8.5%
	Flood	501	447	278	138	47.4%	48.6%	32.2%	14.8%	1.2%	-16.4%	-17.4%	-32.6%
	Totals	**501**	**447**	**392**	**320**	**47.4%**	**48.6%**	**45.4%**	**34.3%**	**1.2%**	**-3.2%**	**-11.1%**	**-13.1%**

Non-Irrigated

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

RIPARIAN

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

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

WETLANDS

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

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

RUSSIAN OLIVE

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

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

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

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

FISHERIES SUMMARY

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

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

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

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

AVIAN

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