County	Yellowstone	**Upstream River Mile**	392.4
Classification	UA: Unconfined anabranching	**Downstream River Mile**	386
General Location	To Laurel	**Length**	6.40 mi (10.30 km)
General Comments	To Laurel; WAI Reach A		

Narrative Summary

Reach A17 is 7.6 miles long and is located just above Laurel. The reach is classified as Unconfined Anabranching (UA), which is characteristically one of the most dynamic reach types on the river. The river is flowing in the alluvial valley with minimal influences of the valley wall and through numerous forested islands. There are sites in Reach A17 where the river has migrated almost 1,000 feet since 1950.

Approximately 13 percent of the bankline in Reach A17 is armored by rock riprap, concrete riprap and flow deflectors. Between 2001 and 2011 the total length of rock riprap increased by about a half of a mile. At RM 387, a ~750 foot long stretch of flow deflectors on the left bank have been flanked, and by fall 2011 the river had migrated about 120 feet behind the flanked armor. The deflectors are still visible in the channel. In some places such as at RM 389.8, bank armor on both sides of the river narrows the corridor to about one channel width, or 1,000 feet.

Over a mile of side channels in Reach A17 were blocked prior to 1950. Two major channels were blocked on the north side of the river, one at the Buffalo Mirage Fishing Access Site at RM 391.5, and the other at Rm 389.5. These channels, as well as other secondary channels that were passively loss, host fairly dense concentrations of Russian olive. Similar to most reaches in Region A, the loss of side channels has been accompanied by an increase in the total river footprint, indicating that flow concentration into the main river channel has caused it to enlarge. Between 1950 and 2001, the size of the channel increased from 560 acres to 645 acres.

Land use in Reach A17 is primarily agricultural, although there are almost 600 acres of urban/exurban development in the reach as the river approaches the City of Laurel. Since 1950, there has been a reduction in flood irrigated acres of about 550 acres, and an increase in pivot irrigation from 0 acres in 1950 to 284 acres in 2011. A total of 383 acres of developed ground are in the mapped Channel Migration Zone; and about 11 percent of the CMZ has been isolated by physical features protecting those land uses.

At RM 388.5, a headgate diverts water into an old side channel that has been converted to a canal on the north side of the river. About ½ mile downstream, the canal is riprapped where it was recently threatened by rapid northward river migration. At this location, the river has migrated over 800 feet northward since 1950. The main channel of the river now flows along the riprapped canal embankment for about 750 feet.

There are corrals that are part of an animal handling facility within 600 feet of the north riverbank at RM 392.

Side channel loss and channel migration in Reach A17 has resulted in relatively high rates of riparian recruitment. Since 1950, there has been 330 acres of land that experience recruitment of new riparian vegetation. Most of that recruitment was in abandoned channels (200 acres) and about 27 acres of recruitment was direct result of channel migration.

Two ice jams have been recorded in Reach A17, in 1996 and 1997. Both occurred during the month of February, and were reported to have occurred at the Laurel Bridge.

There are over 200 acres of mapped wetland in the reach, with most of that emergent marshes and wet meadows. Many of these wetland areas occupy river swales on the floodplain north of the river, or abandoned channels in the active corridor.

Almost 22 acres of Russian olive has been mapped in the floodplain.

Reach A17 was sampled as part of the avian study. The average species richness in Reach A17 was 7.7, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for all sites evaluated is 8. An average of 0.9 Cowbirds (a bird that parasitizes other bird's nests) were observed in cottonwood habitats during the field sampling visits. Reach A17 has lost about two thirds of its riparian forest considered at low risk of cowbird parasitism since 1950. At that time, there were about 28 acres of forest per valley mile considered to be isolated enough from agricultural infrastructure and urban/exurban development to be considered at low risk. By 2011, about 10 acres per valley mile considered low risk remained.

A total of three Potential Species of Concern (PSOCs) were observed in Reach A17 during the avian study, including the Black and White Warbler, Chimney Swift, and Ovenbird. One Species of Concern (SOC), the Bobolink, was also observed in Reach A17.

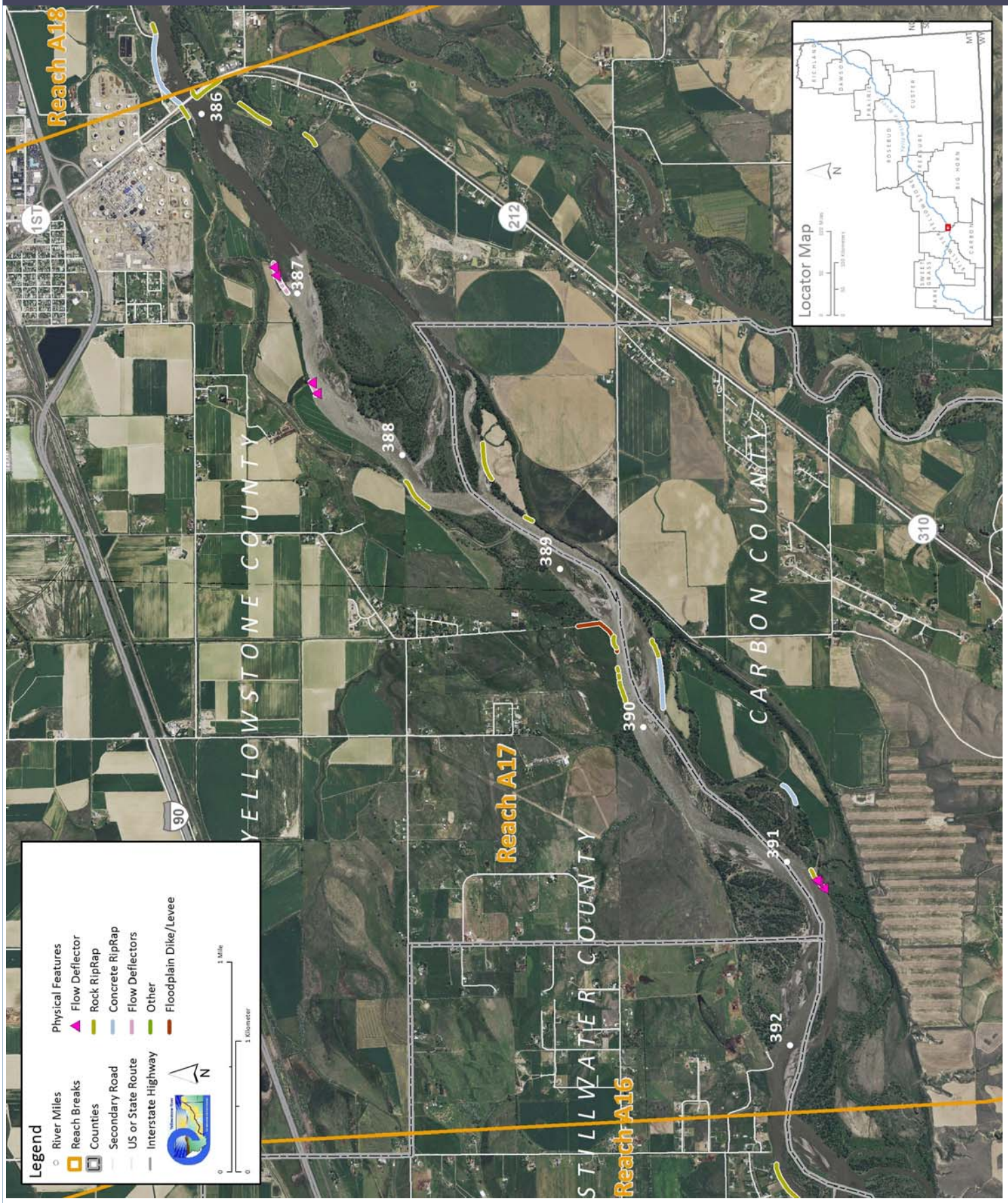
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 16,900 cfs to 15,500 cfs, a drop of about 8 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,320 cfs to 1,780 cfs with human development, a reduction of 23 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A17 include:
•Flanking of flow deflectors and accelerated erosion behind flanked structures

•Physical blockage of over a mile of side channel
•Russian olive colonization in abandoned side channels
•Emergent wetland development in abandoned side channels
•Ice jamming potentially associated with the Laurel Bridge

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A17 include:
•Bank armor removal (flanked flow deflectors), RM 387
•Side channel restoration at RM 391.5 and RM 389.5
•Nutrient management associated with corrals that are part of an animal handling facility at RM 392.
•Russian olive removal (22 acres)
•Wetland management/restoration due to extent of mapped wetland (200 acres)
•Irrigation diversion structure management at headgate on side channel at RM 388.5

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	21.6	114.2

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	16,900	32,200	40,100	44,900	54,600	58,600	67,500	2,320	1,760
Regulated	15,500	30,600	38,600	43,500	53,500	57,600	66,900	1,780	1,680
% Change	-8.28%	-4.97%	-3.74%	-3.12%	-2.01%	-1.71%	-0.89%	-23.28%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	5/14/51 - 6/9/51	B/W	1:28,400	6192500	6000
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	23-Aug-96	B/W		6192500	3730
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2004	Merrick	14-May-04	Color	1:15,840	6192500	4520
2005	NAIP	07/12/2005	color	1-meter pixels	6192500	5960
2005	NAIP	07/08/2005	color	1-meter pixels	6192500	6410
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	USCOE	October 2012	color	1-ft pixel	6192500	2530
2011	NAIP	7/24/2011	Color	1-meter pixels	6192500	13100
2013	NAIP	06/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	3,601	5.3%	6,185	9.1%	2,584
	Flow Deflectors	236	0.3%	230	0.3%	-6
	Concrete RipRap	2,205	3.2%	2,205	3.2%	0
	Between Flow Deflectors	612	0.9%	441	0.6%	-171
	Feature Type Totals	**6,653**	**9.7%**	**9,061**	**13.3%**	**2,408**
Floodplain Control						
	Floodplain Dike/Levee	1,434	2.1%	1,434	2.1%	0
	Feature Type Totals	**1,434**	**2.1%**	**1,434**	**2.1%**	**0**
	Reach Totals	**8,087**	**11.8%**	**10,495**	**15.4%**	**2,408**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	1,227	0	659	0	0	0	0	0
Flow Deflectors/Between FDs	846	0	0	0	0	0	0	0
Rock RipRap	1,132	0	1,250	1,207	0	0	0	0
Totals	**3,205**	**0**	**1,909**	**1,207**	**0**	**0**	**0**	**0**

Bankline/Floodplain Inventory: Time Series

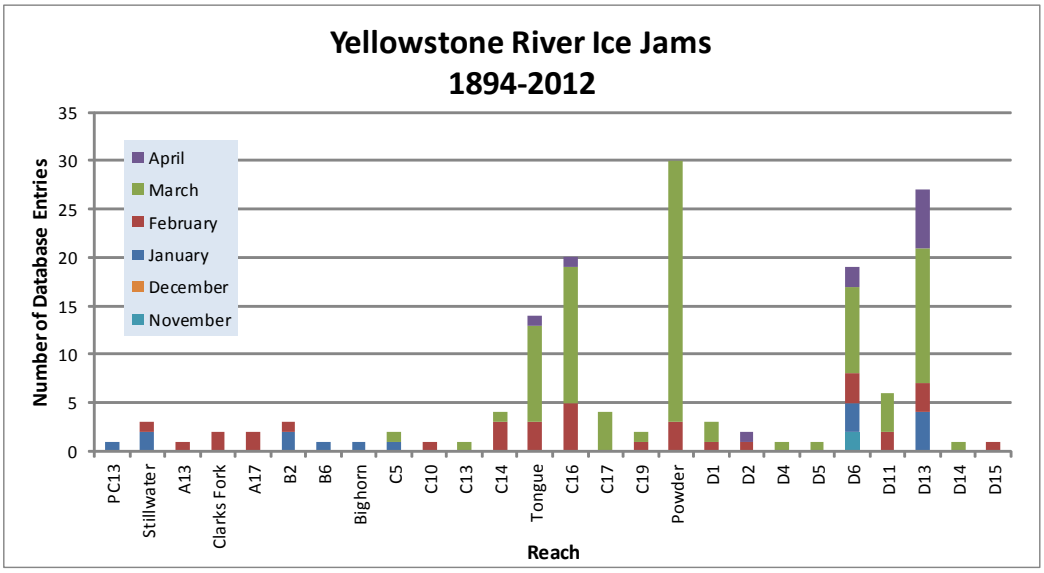
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	32,154	32,838	32,838	33,205	33,965	33,965
	Totals	**32,154**	**32,838**	**32,838**	**33,205**	**33,965**	**33,965**
Other							
	Floodplain Dike/Levee	0	2,677	2,677	2,677	2,677	2,677
	Totals	**0**	**2,677**	**2,677**	**2,677**	**2,677**	**2,677**
Other Off Channel							
	Other	2,200	2,200	2,200	2,200	2,200	2,200
	Floodplain Dike/Levee	0	0	0	412	412	412
	Floodplain Dike/Levee	361	576	576	576	576	576
	Totals	**2,562**	**2,776**	**2,776**	**3,189**	**3,189**	**3,189**
Stream Stabilization							
	Rock RipRap	272	3,692	3,886	4,200	4,200	4,200

Flow Deflector	0	0	0	812	812	812
Concrete RipRap	366	988	988	3,055	3,645	3,645
Totals	**638**	**4,681**	**4,875**	**8,066**	**8,656**	**8,656**
Transportation Encroachment						
Floodplain Dike/Levee	5,461	5,461	5,461	5,461	5,461	5,461
Bridge Approach	3,994	3,994	3,994	3,994	3,994	3,994
Totals	**9,455**	**9,455**	**9,455**	**9,455**	**9,455**	**9,455**

ICE JAMS

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



Jam Date	Jam Type	River Mile	Damages
2/6/1996	NA	386	Flooding
2/21/1997	Freeze-up	386	?

GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% 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)	7,639
Post-1950s (ft)	0

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	10	0.8%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	80	5.9%		
Total Not Isolated (Ac)	1253		1092	
Total Floodplain Area (Ac)	1343		1139	
Total Isolated (Ac)	**90**	**6.7%**	**46**	**9.4%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	49	0	0	**49**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
457	914	2,173	192	9%	78	0	0%

2011 Restricted Migration Area Summary

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

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Public Road	16	0.7%
	Non-Irrigated	45	2.0%
	Irrigated	114	5.0%
	Canal	23	1.0%
Flow Deflectors			
	Irrigated	25	1.1%
Dike/Levee			
	Irrigated	23	1.0%
	Totals	**246**	**10.9%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
358.9	0.0	0.0	18.7	5.7

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	15	15	15	15	0.3%	0.3%	0.3%	0.3%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	54	75	97	103	0.9%	1.3%	1.7%	1.8%
	Totals	**69**	**90**	**112**	**118**	**1.2%**	**1.6%**	**1.9%**	**2.1%**
Agricultural Land									
	Non-Irrigated	2,603	2,243	2,491	2,442	45.2%	39.0%	43.3%	42.4%
	Irrigated	1,927	2,113	1,736	1,668	33.5%	36.7%	30.2%	29.0%
	Totals	**4,530**	**4,356**	**4,227**	**4,110**	**78.7%**	**75.6%**	**73.4%**	**71.4%**
Channel									
	Channel	954	984	934	983	16.6%	17.1%	16.2%	17.1%
	Totals	**954**	**984**	**934**	**983**	**16.6%**	**17.1%**	**16.2%**	**17.1%**
ExUrban									
	ExUrban Other	2	2	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	6	25	62	76	0.1%	0.4%	1.1%	1.3%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	51	52	168	216	0.9%	0.9%	2.9%	3.8%
	Totals	**59**	**80**	**230**	**292**	**1.0%**	**1.4%**	**4.0%**	**5.1%**
Transportation									
	Public Road	41	41	41	41	0.7%	0.7%	0.7%	0.7%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	10	10	10	10	0.2%	0.2%	0.2%	0.2%
	Totals	**50**	**50**	**50**	**50**	**0.9%**	**0.9%**	**0.9%**	**0.9%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	21	21	21	0.0%	0.4%	0.4%	0.4%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	22	0	0	0	0.4%	0.0%	0.0%	0.0%
	Urban Industrial	74	177	182	182	1.3%	3.1%	3.2%	3.2%
	Totals	**95**	**199**	**204**	**204**	**1.7%**	**3.5%**	**3.5%**	**3.5%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	203	284	284	0.0%	4.7%	6.7%	6.9%	4.7%	2.1%	0.2%	6.9%
	Flood	1,927	1,910	1,452	1,384	42.5%	43.8%	34.4%	33.7%	1.3%	-9.5%	-0.7%	-8.9%
	Totals	**1,927**	**2,113**	**1,736**	**1,668**	**42.5%**	**48.5%**	**41.1%**	**40.6%**	**6.0%**	**-7.4%**	**-0.5%**	**-2.0%**

Non-Irrigated

Multi-Use	1,484	1,093	1,201	1,182	32.8%	25.1%	28.4%	28.8%	-7.7%	3.3%	0.4%	-4.0%
Hay/Pasture	1,119	1,150	1,290	1,260	24.7%	26.4%	30.5%	30.7%	1.7%	4.1%	0.1%	6.0%
Totals	**2,603**	**2,243**	**2,491**	**2,442**	**57.5%**	**51.5%**	**58.9%**	**59.4%**	**-6.0%**	**7.4%**	**0.5%**	**2.0%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.2	0.5	0.0	0.3	0.0	1.0	2.4	1.3	0.4
Max	22.7	88.6	21.9	213.6	142.1	156.2	89.4	52.3	129.8
Average	5.5	16.6	5.6	36.2	22.2	32.2	19.9	21.3	22.1
Sum	83.1	182.6	78.5	723.3	777.5	677.1	258.8	191.6	331.4

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	255.8
Channel to Riparian (acres)	236.0
Riparian Encroachment (acres)	**-19.8**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	227.5
1950s Floodplain Mapped as 2011 Channel (Ac)	100.2
Total Recruitment (1950s to 2011)(Ac)	**327.7**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	9.4	203.4	13.4	0.0	**226.2**
Acres/Valley Mile	1.6	35.6	2.3	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	21.84	6.68%	182.62	1.10	3.47	1.43

FISHERIES SUMMARY

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

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

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

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

Low Flow Fisheries Habitat Mapping

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

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

Yellowstone River Reach Narratives — Reach A18

County	Yellowstone	**Upstream River Mile**	386
Classification	UA: Unconfined anabranching	**Downstream River Mile**	383.5
General Location	To Clarks Fork	**Length**	2.50 mi (4.02 km)
General Comments	To Clark Fork; land use change to row crops; WAI Reach A		

Narrative Summary

Reach A18 is 2.5 miles long and extends from Laurel to the mouth of the Clarks Fork River. The reach is classified as Unconfined Anabranching (UA), which is characteristically one of the most dynamic reach types on the river. The reach has one large island and even though it is fairly intensively armored through Laurel, there has been over 1,100 feet of southward channel migration since 1950 at one location about ½ mile downstream of the bridge.

Reach A18 is perhaps best known by the series of pipeline crossings below the Laurel Bridge. In 2011, floodwaters on the Yellowstone River peaked on July 2 at 70,600 cfs, which is an estimated 25-50 year flood event. On July 1, the day before the peak, a 12-inch diameter crude oil pipeline called the ExxonMobil Silvertip Pipeline, ruptured just downstream of the bridge in Reach A18. The pipeline was originally installed in a trench across the river that was 5-7 feet deep. The rupture spilled an estimated 50,000 gallons of oil into the Yellowstone River; the incident received national attention and millions of dollars were spent on cleanup. The Silvertip Pipeline and several others at this location have been replaced by HDD (Horizontal Directionally Drilled) lines.

The industrial land uses at Laurel uses coupled with the dynamic nature of the Yellowstone River in Reach A18 has resulted in the armoring of almost 40 percent of the river in this reach. That armor consists of rock riprap, concrete riprap, and flow deflectors. Almost all of the armor is located on the north bank where it protects the City of Laurel sewage treatment facility, as well as a canal that leaves the river at RM 385.7. There is one small section of concrete armor on the north bank, and it appears that the upper 300 feet of this armor has been flanked and now is visible in the middle of the river. Recent concerns over the main intake structure for the city's water supply sheds some light on the dynamics of the river, and potentially the influence of high density bank armor on channel stability. The 2011 flood evidently caused the river to downcut at the intake, perching the structure, such that there are current efforts in motion to relocate the intake several miles upstream. This downcutting may be related to the high density of armor between Laurel and Billings that effectively focuses flow into the main channel and can drive channel incision (downcutting). Reach conditions just downstream in Reach B1 support this hypothesis.

There are over three miles of mapped dikes in Reach A18. Dikes, levees, and transportation encroachment features have isolated about one half of the historic 100-year floodplain in the reach. Almost 17 percent of the 5-year floodplain has become isolated from the river. Most of the isolated 100-year floodplain area is south of the river, between the Yellowstone and Clarks Fork Rivers.

Land use in Reach A18 is primarily agricultural, although there are almost 380 acres of urban/exurban development in the reach as the river passes south of the City of Laurel. All of the irrigated land in Reach A18 is in flood irrigation. A total of 110 acres of developed ground are in the mapped Channel Migration Zone; and the over 90 percent of that is in urban/exurban land use. A total of 31 percent of the CMZ has become isolated by physical features.

Riparian mapping indicates that since 1950, about 67 acres in the reach were cleared to support irrigation and other land uses. There are about 18 acres of mapped Russian olive in the floodplain.

Since 1950, about 150 acres of land in Reach A18 was colonized by new riparian vegetation. There are over 140 acres of mapped emergent wetland in the reach, which consists primarily of emergent marshes and wet meadows.

Almost 18 acres of Russian olive has been mapped in the floodplain.

Reach A18 was sampled as part of the avian study. The average species richness in Reach A17 was 7.1, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for all sites evaluated is 8. On average, of 0.9 Cowbirds were observed in cottonwood habitats during the field sampling visits. Reach A18 has lost all of its riparian forest considered at low risk of cowbird parasitism since 1950. At that time, there were 3.4 acres of forest per valley mile considered to be isolated enough from agricultural infrastructure and urban/exurban development to be considered at low risk. By 2011, that had been reduced to zero.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 16,900 cfs to 15,500 cfs, a drop of about 8 percent. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,780 cfs to 1,950 cfs with human development, a reduction of 30 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A18 include:
•Flanking of concrete armor
•Pipeline rupture in highly armored reach
•Water intake perching in highly armored reach
•Russian olive colonization
•Emergent wetland development in abandoned side channels

•Floodplain isolation at confluence between Clarks Fork and Yellowstone River from transportation-related infrastructure
•Extensive CMZ encroachment in urbanized reach

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A18 include:
•Irrigation diversion structure management at headgate on at a canal at RM 385.7
•Flanked concrete armor removal RM 384
•Russian olive removal (18 acres)
•Floodplain restoration between lower Clarks Fork River and Yellowstone River
•Pipeline Management for several crossings at Laurel.

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	19.1	120.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	16,900	32,200	40,100	44,900	54,600	58,600	67,500	2,780	1,760
Regulated	15,500	30,600	38,600	43,500	53,500	57,600	66,900	1,950	1,680
% Change	-8.28%	-4.97%	-3.74%	-3.12%	-2.01%	-1.71%	-0.89%	-29.86%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	14-May-51	B/W	1:28,400	6192500	5520
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS DOQQ	23-Aug-96	B/W		6192500	3730
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2004	Merrick	14-May-04	Color	1:15,840	6192500	4520
2005	NAIP	07/12/2005	color	1-meter pixels	6192500	5960
2005	NAIP	07/08/2005	color	1-meter pixels	6192500	6410
2009	NAIP	7/7/2009	Color	1-meter pixels	6192500	11300
2011	USCOE	October 2012	color	1-ft pixel	6192500	2530
2011	NAIP	7/24/2011	Color	1-meter pixels	6192500	13100
2013	NAIP	06/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	3,665	14.7%	3,885	15.6%	220
	Flow Deflectors	570	2.3%	628	2.5%	58
	Concrete RipRap	4,519	18.2%	3,783	15.2%	-736
	Car Bodies	190	0.8%	190	0.8%	0
	Between Flow Deflectors	897	3.6%	897	3.6%	0
	Feature Type Totals	**9,841**	**39.6%**	**9,382**	**37.7%**	**-459**
	Reach Totals	**9,841**	**39.6%**	**9,382**	**37.7%**	**-459**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Car Bodies	0	190	0	0	0	0	0	0
Concrete RipRap	1,968	754	538	262	0	0	0	1,640
Flow Deflectors/Between FDs	0	0	1,466	0	0	0	0	0
Rock RipRap	0	0	1,653	2,011	0	0	0	0
Totals	**1,968**	**945**	**3,657**	**2,273**	**0**	**0**	**0**	**1,640**

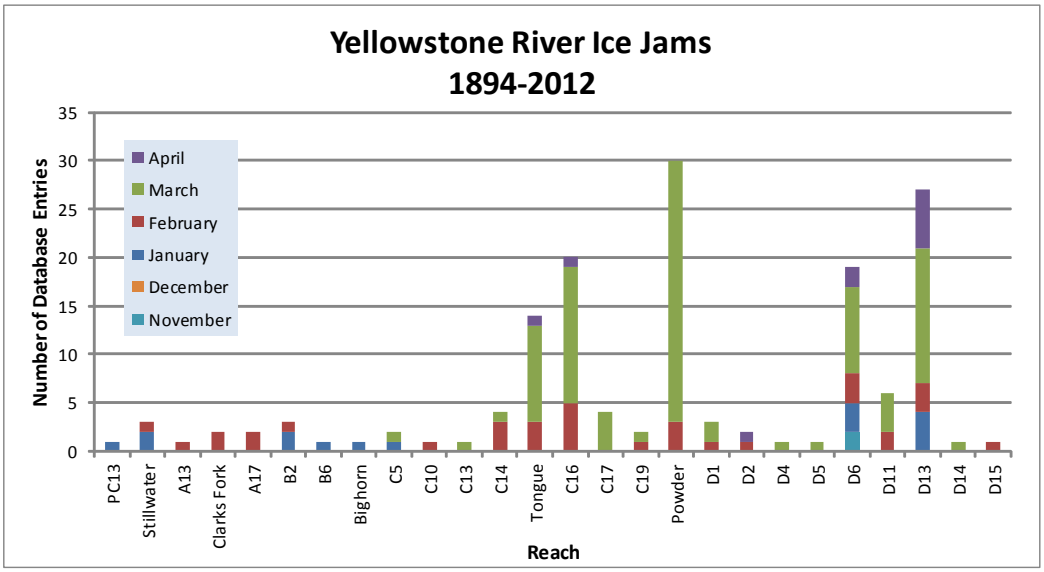
Bankline/Floodplain Inventory: Time Series

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

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	18,079	19,411	20,171	20,171	20,171	20,171
	Totals	**18,079**	**19,411**	**20,171**	**20,171**	**20,171**	**20,171**
Stream Stabilization							
	Rock RipRap	121	2,374	2,374	3,576	3,576	3,576
	Flow Deflector	0	0	0	1,467	1,467	1,467
	Concrete RipRap	2,825	2,825	2,825	4,648	4,648	4,648
	Car Bodies	0	0	569	569	569	569
	Totals	**2,946**	**5,199**	**5,769**	**10,260**	**10,260**	**10,260**
Transportation Encroachment							
	Other	912	912	912	912	912	912
	County Road	11,313	13,192	13,192	13,192	13,192	13,192
	Bridge Approach	1,153	1,153	1,153	1,153	1,153	1,153
	Totals	**13,377**	**15,257**	**15,257**	**15,257**	**15,257**	**15,257**

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	13,798	13,021	1.94	1950 to 1976:	23.49%
1976	12,653	17,718	2.40	1976 to 1995:	-13.22%
1995	12,533	13,573	2.08	1995 to 2001:	5.22%
2001	12,433	14,814	2.19	1950 to 2001:	12.76%
Change 1950 - 2001	**-1,366**	**1,794**	**0.25**		

Length of Side Channels Blocked

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

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	34	6.1%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	269	47.9%		
Total Not Isolated (Ac)	258		354	
Total Floodplain Area (Ac)	562		369	
Total Isolated (Ac)	**304**	**54.0%**	**15**	**17.0%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	1	0	0	**1**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
379	759	884	275	31%	0	0	0%

2011 Restricted Migration Area Summary

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	13	1.5%
RipRap			
	Urban Industrial	37	4.2%
	Public Road	88	9.9%
	Canal	97	11.0%
Flow Deflectors			
	Canal	39	4.4%
	Totals	**275**	**31.1%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
0.0	0.0	0.0	100.9	8.6

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	22	22	22	22	0.8%	0.8%	0.8%	0.8%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	25	40	28	25	0.9%	1.4%	1.0%	0.9%
	Totals	**47**	**62**	**49**	**46**	**1.6%**	**2.2%**	**1.7%**	**1.6%**
Agricultural Land									
	Non-Irrigated	1,456	999	986	874	50.7%	34.8%	34.4%	30.5%
	Irrigated	946	904	861	894	33.0%	31.5%	30.0%	31.1%
	Totals	**2,402**	**1,903**	**1,848**	**1,768**	**83.7%**	**66.3%**	**64.4%**	**61.6%**
Channel									
	Channel	368	672	646	657	12.8%	23.4%	22.5%	22.9%
	Totals	**368**	**672**	**646**	**657**	**12.8%**	**23.4%**	**22.5%**	**22.9%**
ExUrban									
	ExUrban Other	0	6	6	0	0.0%	0.2%	0.2%	0.0%
	ExUrban Undeveloped	0	0	0	61	0.0%	0.0%	0.0%	2.1%
	ExUrban Industrial	0	27	35	35	0.0%	0.9%	1.2%	1.2%
	ExUrban Commercial	6	11	21	21	0.2%	0.4%	0.7%	0.7%
	ExUrban Residential	21	154	199	216	0.7%	5.4%	6.9%	7.5%
	Totals	**27**	**198**	**260**	**332**	**0.9%**	**6.9%**	**9.1%**	**11.6%**
Transportation									
	Public Road	23	23	23	23	0.8%	0.8%	0.8%	0.8%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**23**	**23**	**23**	**23**	**0.8%**	**0.8%**	**0.8%**	**0.8%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	1	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	2	11	43	43	0.1%	0.4%	1.5%	1.5%
	Totals	**2**	**11**	**43**	**43**	**0.1%**	**0.4%**	**1.5%**	**1.5%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	946	904	861	894	39.4%	47.5%	46.6%	50.5%	8.1%	-0.9%	3.9%	11.2%
	Totals	**946**	**904**	**861**	**894**	**39.4%**	**47.5%**	**46.6%**	**50.5%**	**8.1%**	**-0.9%**	**3.9%**	**11.2%**

Non-Irrigated

Multi-Use	1,143	749	875	749	47.6%	39.3%	47.4%	42.3%	-8.2%	8.0%	-5.0%	-5.2%
Hay/Pasture	313	250	111	126	13.0%	13.1%	6.0%	7.1%	0.1%	-7.1%	1.1%	-5.9%
Totals	**1,456**	**999**	**986**	**874**	**60.6%**	**52.5%**	**53.4%**	**49.5%**	**-8.1%**	**0.9%**	**-3.9%**	**-11.2%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	1.3	0.2	1.1	0.0	0.0	1.2	0.3	11.2	2.2
Max	48.1	15.6	36.1	129.9	132.9	148.2	67.2	88.5	61.0
Average	16.7	7.4	14.0	22.2	16.3	20.0	16.5	26.7	23.0
Sum	234.4	103.2	125.9	355.0	341.4	319.6	115.3	160.1	206.9

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	191.3
Channel to Riparian (acres)	134.1
Riparian Encroachment (acres)	**-57.2**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	66.2
1950s Floodplain Mapped as 2011 Channel (Ac)	83.4
Total Recruitment (1950s to 2011)(Ac)	**149.5**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	15.8	139.7	33.2	0.0	**188.7**
Acres/Valley Mile	7.7	68.2	16.2	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	17.94	2.68%	31.36	1.05	1.75	1.00

FISHERIES SUMMARY

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

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

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

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

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	58.2	46.6	10.1%
Rip Rap Bottom	47.0	4.0	0.9%
Secondary Channel	84.1	55.9	12.1%
Secondary Channel (Seasonal)	67.3	22.0	4.7%
Channel Crossover	24.3	28.1	6.1%
Point Bar		7.7	1.7%
Side Bar		16.7	3.6%
Mid-channel Bar		36.7	7.9%
Island	182.7	182.7	39.4%
Dry Channel		63.3	13.7%

AVIAN

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

Bird Species Observed in Reach/Region

Species of Concern | Potential Species of Concern

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.

County	Yellowstone	**Upstream River Mile**	383.5
Classification	UB: Unconfined braided	**Downstream River Mile**	368.3
General Location	Laurel to Billings	**Length**	15.20 mi (24.46 km)
General Comments	Extensive armoring u/s Billings; WAI Reaches B,C,D		

Narrative Summary

Reach B1, located in Yellowstone County, extends from the mouth of the Clark Fork River to Billings. It is approximately 15.4 miles long, extending from RM 367.0 to 382.4. It is an Unconfined Braided (UB) reach type indicating minimal influence of the valley wall coupled by extensive open gravel bars and low flow channels. Human impacts in Reach B1 include early bridge construction and stream corridor narrowing, flow consolidation through diking and bank armoring, and loss of side channel due to physical blockages and apparent downcutting. Flow alterations in this reach have been substantial; the mean annual flood has dropped an estimated 17 percent due to human influences, and summer low flows have dropped by 42 percent.

In total there are 57,118 feet of bank armor in Reach B1, which equates to 10.82 miles of bank armor in a 15.4 mile long reach of river. Concrete riprap is the most prevalent type of armor, with about 5.5 miles present in 2011, even after the loss of 2,870 feet of concrete armor protection between 2001 and 2011. There are almost four miles of rock riprap, over 4,000 feet of which was constructed since 2001. There are also 7,616 feet of flow deflectors in the reach, and about 2,500 feet of those flow deflectors were built between 2001 and 2011. The most rapid expansion of armor occurred between 1950 and 1995, when the total length of bank protection expanded from 14,872 feet to 47,339 feet.

Numerous bank armor structures have been eroded out in Reach B1. Typically flanked, failed armor was identified at the following locations:
•RM 383L: 330 feet of flow deflectors totally lost
•RM 382.3R: lower 175 feet of concrete riprap flanked
•RM 281.5R: upper 400 feet of concrete riprap flanked: Idled crude oil pipeline is less than 200 feet behind this flanked armor
•RM 380.2R: lower 600 feet of concrete armor flanked
•RM 377.8: upper 540 feet of concrete armor flanked
•RM 373.8R: upper 300 feet and lower 270 feet of concrete armor flanked

The loss of side channel length through time has been extensive. Prior to 1950, almost a mile of side channels had been blocked on the south side of the river at RM 373.8 and at the South Billings Blvd Bridge at RM 371. Since 1950, another 14,800 feet have been blocked by dikes. One major blockage is located about 2 miles upstream of the Duck Creek Bridge at RM 381 and another near the gravel pit/trailer park complex at RM 373. Other side channels have been lost passively, without blockages. In total, Reach B1 has been characterized by a loss of seven miles of side channel length between 1950 and 2001, the majority of which occurred between 1976 and 1996.

A review of available data indicate that the loss of side channels in Reach B1 is both directly and indirectly related to bank stabilization within the reach. Between 1950 and 1976, a series of dikes were constructed upstream of South Billings Blvd to block the course of a primary channel, isolating several thousand feet of channel. Womack (2000) notes that “the greatest measureable change has occurred due to abandonment of secondary channels, primarily due to construction of dikes and secondarily due to channel armoring. A relatively short dike at the upstream end of a braided reach can have a disproportionate effect, because it may effectively eliminate miles of channel”. These blockages are associated with some of the braiding parameter reduction in Reach B1. However, the most loss of side channels occurred after 1976, when the dikes above South Billings Blvd. were already in place. Some of these channels were abandoned due to blockage by dikes, and other locations of channel abandonment and braiding parameter reduction show no apparent direct relationship to physical features.

The side channels that were passively abandoned in Reach B1 are commonly perched above the main Yellowstone River channel. This perching indicates that abandonment may be related to downcutting of the main channel. Womack (2000) noted that width to depth ratios decreased in heavily armored reaches due to flow consolidation in a single channel. Womack suggests that channel confinement and consolidation into fewer channels has resulted in downcutting and reduction in width to depth ratio. Flow alterations have also likely contributed to side channel abandonment.

Several bridges were constructed in Reach B1 prior to 1950. These bridges all constrict the natural meander corridor of the river and have been associated with channel downcutting. Womack (2000) showed seven feet of degradation immediately upstream of the South Billings Blvd Bridge.

The primary land use in the reach is non-irrigated agriculture although several thousand acres of agricultural land has been developed since 1950. In 2011, there were about 3,000 acres of land under flood irrigation and 240 acres under pivot in Reach B1. Between 1950 and 2011, the extent of urban/exurban land use expanded from 310 acres to over 2,000 acres. The development has extended into the Channel Migration Zone (CMZ). A total of 810 acres of CMZ are developed, with 242 acres of ground developed for urban/exurban use and 84 acres in pivot irrigation. Another 470 acres of land in the CMZ are under flood irrigation. As a consequence of extensive development in the CMZ, about 25 percent of the total CMZ footprint has become restricted due to armoring and dike construction.

There is one animal handling facility within 300 feet of the north riverbank just downstream of the Duck Creek Bridge at RM 377.7.

A total of 610 acres of the historic 100-year floodplain has become isolated from the river, which is 14 percent of the total 100-year

floodplain footprint. Most of the 100-year floodplain isolation is due to transportation infrastructure. Similarly, about 13 percent of the 5-year floodplain (270 acres) has been isolated by transportation infrastructure. There are 184 acres of flood irrigated land in the 5-year floodplain, and 73 acres in pivot. Whereas most of the isolated 100-year floodplain area is behind the I-90 corridor in the city of Billings, most of the isolated 5-year area is in the stream corridor, which supports the interpretation that some downcutting in the reach has perched historic channels and floodplain area.

There are several pipeline crossings in Reach B1. At RM 382, two pipelines cross under the river; one is a natural gas pipeline owned by NW Energy LLC, and the other is an idled crude oil pipeline owned by Conoco Phillips. The idled crude oil pipeline follows the river close to the bank at RM 281.5R where concrete armor has been flanked. There are four pipelines at South Billings Blvd; the one of these pipelines that was built to carry crude oil has been idled under nitrogen. The other pipelines are all natural gas.

Over 400 acres of wetland have been mapped in the reach, with most of that (270 acres) emergent wetland marsh that is located primarily in the active stream corridor and in abandoned channels. A total of 42 acres of Russian olive have been mapped in the reach, and these trees are dispersed throughout the corridor.

Reach B1 was sampled as part of the avian study. The average species richness in Reach B1 was 8.0, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. One bird Species of Concern (SOC), the Black-Billed Cuckoo, was identified in the reach. Three bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were also found, including the Black and White Warbler, Chimney Swift, and Ovenbird. Since 1950, Reach B1 has lost all of its forest that would be considered at low risk of cowbird infestation due to its separation from agricultural infrastructure. In 1950, about 3.5 acres of forest per valley mile were identified as low risk and by 2001 that forest area had been reduced to zero.

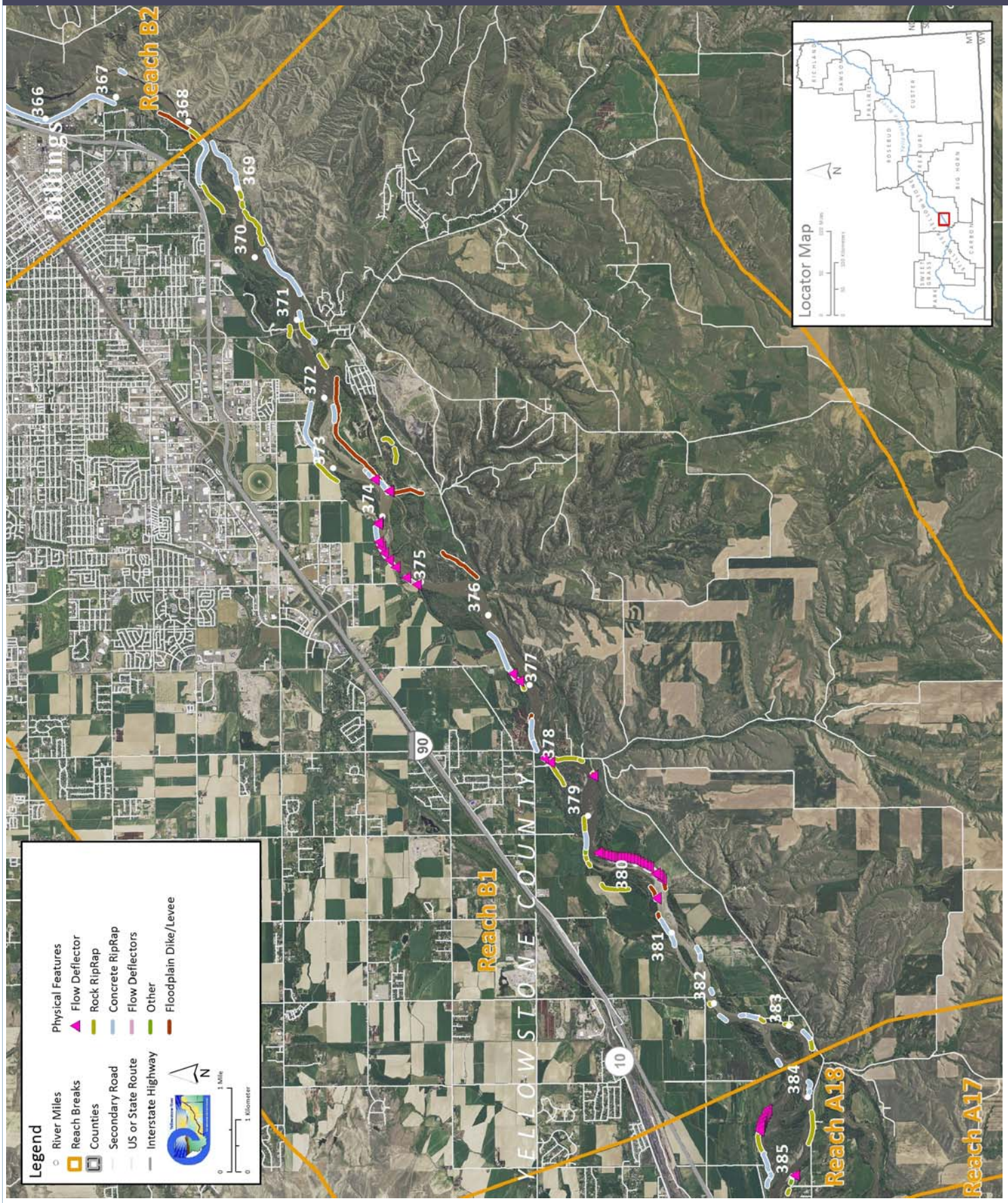
Reach B1 was sampled as part of the fisheries study. A total of 31 fish species were sampled in the reach, and none of these species have been identified by the Montana Natural Heritage Program as Species of Concern (SOC).

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 22,800 cfs to 18,900 cfs, a drop of about 17 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,900 cfs to 2,000 cfs with human development, a reduction of 31 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,836 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B1 include:
•Blockage of miles of side channel
•Extensive armoring with CMZ encroachment
•Passive loss of major side channels due to downcutting and flow alterations

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B1 include:
•Side channel restoration at RM 381 and RM 373
•Pipeline crossing management – natural gas pipeline at RM 382
•Flanked armor removal at RM 383, RM 382.3, RM 281.5, RM 380.2, RM 377.8, and RM 373.8
•CMZ management due to extent of current CMZ restriction (25 percent)
•Russian olive removal
•Pipeline management at crossings and also where concrete armor has flanked where idled crude oil pipeline runs parallel to bank at RM 285.1R
•Nutrient management at corrals that are part of an animal handling facility within 300 feet of river at RM 377.7 just downstream of Duck Creek Bridge.

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	3.9	123.1

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	22,800	42,700	52,800	58,900	71,200	76,200	87,400	2,900	3,846
Regulated	18,900	38,500	48,900	55,200	68,300	73,700	85,900	2,000	2,227
% Change	-17.11%	-9.84%	-7.39%	-6.28%	-4.07%	-3.28%	-1.72%	-31.03%	-42.10%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	5/14/51 - 5/15/51	B/W	1:28,400	6214500	12000
1976	USCOE	28-Sep-76	B/W	1:24,000	6214500	5940
1995	USGS DOQQ	23-Aug-96	B/W		6214500	4500
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	15-May-04	Color	1:15,840	6214500	5960
2005	NAIP	07/12/2005	color	1-meter pixels	6214500	12600
2005	NAIP	07/08/2005	color	1-meter pixels	6214500	11400
2009	NAIP	7/7/2009	Color	1-meter pixels	6214500	20900
2009	NAIP	7/5/2009	Color	1-meter pixels	6214500	23800
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/24/2011	Color	1-meter pixels	6214500	22800
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	16,336	10.1%	20,754	12.9%	4,418
	Flow Deflectors	1,228	0.8%	2,034	1.3%	806
	Concrete RipRap	31,621	19.6%	28,751	17.8%	-2,870
	Car Bodies	942	0.6%	718	0.4%	-225
	Between Flow Deflectors	3,835	2.4%	5,582	3.5%	1,748
	Feature Type Totals	**53,961**	**33.5%**	**57,839**	**35.9%**	**3,877**
Floodplain Control						
	Transportation Encroachment	3,902	2.4%	3,902	2.4%	0
	Floodplain Dike/Levee	23,985	14.9%	23,985	14.9%	0
	Feature Type Totals	**27,887**	**17.3%**	**27,887**	**17.3%**	**0**
	Reach Totals	**81,848**	**50.8%**	**85,726**	**53.2%**	**3,877**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Car Bodies	541	0	400	0	0	0	0	0
Concrete RipRap	7,964	9,719	3,582	951	0	0	0	9,394
Flow Deflectors/Between FDs	4,566	0	328	0	0	0	0	0
Rock RipRap	6,262	0	495	5,169	0	0	0	4,546
Totals	**19,332**	**9,719**	**4,805**	**6,120**	**0**	**0**	**0**	**13,940**

Bankline/Floodplain Inventory: Time Series

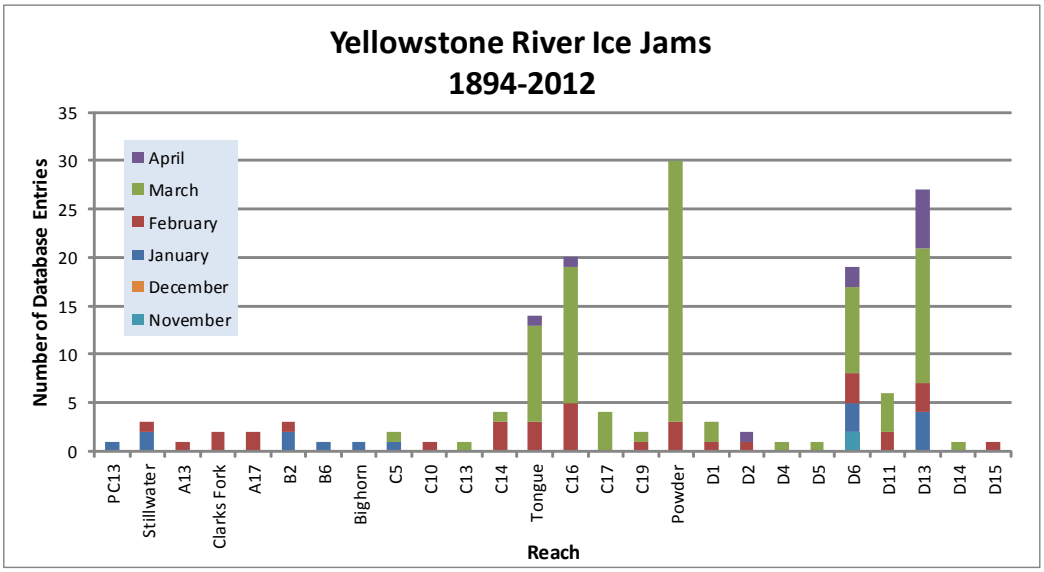
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	103	1,954	1,954	1,954	2,284	2,284
	Totals	**103**	**1,954**	**1,954**	**1,954**	**2,284**	**2,284**
Other							
	Floodplain Dike/Levee	0	0	1,210	1,210	1,210	1,210
	Totals	**0**	**0**	**1,210**	**1,210**	**1,210**	**1,210**
Other Off Channel							
	Floodplain Dike/Levee	0	5,137	12,336	18,261	19,342	19,342
	Floodplain Dike/Levee	4,058	7,900	7,370	19,666	19,666	19,666

Totals	**4,058**	**13,037**	**19,706**	**37,927**	**39,008**	**39,008**
Stream Stabilization						
Rock RipRap	7,373	18,198	19,335	19,832	22,285	22,285
Flow Deflector	1,589	914	914	6,024	6,024	6,024
Concrete RipRap	5,569	16,943	25,910	31,257	31,544	31,544
Car Bodies	341	1,039	1,180	1,180	1,180	1,180
Totals	**14,872**	**37,094**	**47,339**	**58,293**	**61,033**	**61,033**
Transportation Encroachment						
Other	11,368	14,402	15,081	15,295	15,295	15,295
Interstate	0	7,583	7,583	7,583	7,583	7,583
County Road	9,792	17,180	15,814	15,814	15,814	15,814
Bridge Approach	3,230	5,909	5,909	5,909	5,909	5,909
Totals	**24,390**	**45,075**	**44,387**	**44,601**	**44,601**	**44,601**

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	79,617	120,036	2.51	1950 to 1976:	-3.18%
1976	77,560	110,757	2.43	1976 to 1995:	-18.58%
1995	81,942	80,054	1.98	1995 to 2001:	2.88%
2001	80,555	83,280	2.03	1950 to 2001:	-18.90%
Change 1950 - 2001	**938**	**-36,757**	**-0.47**		

Length of Side Channels Blocked

Pre-1950s (ft)	4,970
Post-1950s (ft)	14,812

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	11	0.2%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	600	13.3%		
Total Not Isolated (Ac)	3899		3470	
Total Floodplain Area (Ac)	4509		3737	
Total Isolated (Ac)	**611**	**13.5%**	**267**	**13.1%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	184	3	73	**260**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
362	724	4,742	1,192	25%	355	91	26%

2011 Restricted Migration Area Summary

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

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Other Infrastructure	6	0.1%
	Non-Irrigated	28	0.5%
RipRap/Flow Deflectors			
	Irrigated	192	3.8%
RipRap			
	Public Road	178	3.5%
	Other Infrastructure	35	0.7%
	Non-Irrigated	227	4.5%
	Irrigated	142	2.8%
	Exurban Residential	52	1.0%
	Canal	10	0.2%
Dike/Levee			
	Non-Irrigated	416	8.1%
	Totals	**1,285**	**25.2%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
466.6	0.0	83.9	241.9	16.5

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	21	21	21	21	0.2%	0.2%	0.2%	0.2%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	200	222	294	333	1.5%	1.7%	2.3%	2.6%
	Totals	**221**	**243**	**316**	**354**	**1.7%**	**1.9%**	**2.4%**	**2.7%**
Agricultural Land									
	Non-Irrigated	6,549	5,213	4,985	4,742	50.3%	40.1%	38.3%	36.5%
	Irrigated	2,905	3,060	3,637	3,190	22.3%	23.5%	28.0%	24.5%
	Totals	**9,454**	**8,273**	**8,623**	**7,931**	**72.7%**	**63.6%**	**66.3%**	**61.0%**
Channel									
	Channel	2,913	3,120	2,221	2,318	22.4%	24.0%	17.1%	17.8%
	Totals	**2,913**	**3,120**	**2,221**	**2,318**	**22.4%**	**24.0%**	**17.1%**	**17.8%**
ExUrban									
	ExUrban Other	0	6	107	125	0.0%	0.0%	0.8%	1.0%
	ExUrban Undeveloped	10	17	27	22	0.1%	0.1%	0.2%	0.2%
	ExUrban Industrial	3	65	107	194	0.0%	0.5%	0.8%	1.5%
	ExUrban Commercial	0	0	0	7	0.0%	0.0%	0.0%	0.1%
	ExUrban Residential	129	240	302	362	1.0%	1.8%	2.3%	2.8%
	Totals	**142**	**328**	**544**	**710**	**1.1%**	**2.5%**	**4.2%**	**5.5%**
Transportation									
	Public Road	102	94	98	103	0.8%	0.7%	0.8%	0.8%
	Interstate	0	48	48	48	0.0%	0.4%	0.4%	0.4%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**102**	**141**	**145**	**151**	**0.8%**	**1.1%**	**1.1%**	**1.2%**
Urban									
	Urban Other	0	23	25	25	0.0%	0.2%	0.2%	0.2%
	Urban Residential	148	608	876	1,020	1.1%	4.7%	6.7%	7.8%
	Urban Commercial	0	14	16	19	0.0%	0.1%	0.1%	0.1%
	Urban Undeveloped	0	134	100	109	0.0%	1.0%	0.8%	0.8%
	Urban Industrial	27	123	142	369	0.2%	0.9%	1.1%	2.8%
	Totals	**175**	**902**	**1,159**	**1,542**	**1.3%**	**6.9%**	**8.9%**	**11.9%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	26	26	0.0%	0.0%	0.3%	0.3%	0.0%	0.3%	0.0%	0.3%
	Pivot	0	0	192	241	0.0%	0.0%	2.2%	3.0%	0.0%	2.2%	0.8%	3.0%
	Flood	2,905	3,060	3,420	2,922	30.7%	37.0%	39.7%	36.8%	6.3%	2.7%	-2.8%	6.1%
	Totals	**2,905**	**3,060**	**3,637**	**3,190**	**30.7%**	**37.0%**	**42.2%**	**40.2%**	**6.3%**	**5.2%**	**-2.0%**	**9.5%**

Non-Irrigated

Multi-Use	3,762	3,367	4,503	4,089	39.8%	40.7%	52.2%	51.6%	0.9%	11.5%	-0.7%	11.8%
Hay/Pasture	2,787	1,846	482	653	29.5%	22.3%	5.6%	8.2%	-7.2%	-16.7%	2.6%	-21.2%
Totals	**6,549**	**5,213**	**4,985**	**4,742**	**69.3%**	**63.0%**	**57.8%**	**59.8%**	**-6.3%**	**-5.2%**	**2.0%**	**-9.5%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.9	0.4	0.5	0.4	0.2	0.8	1.9	1.1	0.0
Max	44.3	211.9	49.8	97.4	139.8	253.9	132.1	43.4	168.8
Average	11.5	12.8	12.8	27.4	20.1	34.6	25.3	15.1	17.8
Sum	402.4	539.4	500.4	1,262.6	1,367.5	1,385.2	556.9	272.5	446.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	509.3
Channel to Riparian (acres)	718.4
Riparian Encroachment (acres)	**209.1**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	763.3
1950s Floodplain Mapped as 2011 Channel (Ac)	185.9
Total Recruitment (1950s to 2011)(Ac)	**949.2**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	81.4	269.3	70.9	0.0	**421.6**
Acres/Valley Mile	6.2	20.4	5.4	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	41.60	1.83%	90.90	8.05	10.44	3.48

FISHERIES SUMMARY

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

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

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

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

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
☑	☑	Bigmouth buffalo	☑	☑	Flathead chub	☐	☐	Northern redbelly dace	☑	☑	Stonecat
☐	☑	Black bullhead	☐	☐	Freshwater drum	☐	☐	Pallid sturgeon	☐	☐	Sturgeon chub
☑	☑	Black crappie	☑	☑	Goldeye	☑	☑	Pumpkinseed	☑	☑	Sucker species
☐	☐	Blue sucker	☑	☑	Green sunfish	☑	☑	Rainbow trout	☑	☑	Sunfish species
☑	☑	Bluegill	☑	☑	Lake chub	☑	☑	River carpsucker	☐	☐	Walleye
☑	☑	Brook stickleback	☑	☑	Largemouth bass	☐	☐	Rock bass	☑	☑	Western silvery minnow
☑	☑	Brown trout	☑	☑	Longnose dace	☐	☑	Sand shiner	☐	☐	White bass
☑	☑	Burbot	☑	☑	Longnose sucker	☐	☑	Sauger	☑	☑	White crappie
☐	☐	Catfish species	☑	☑	Minnow species	☑	☑	Shorthead redhorse	☑	☑	White sucker
☑	☑	Channel catfish	☐	☑	Mottled sculpin	☐	☐	Shortnose gar	☐	☐	Yellow bullhead
☑	☑	Common carp	☑	☑	Mountain sucker	☐	☐	Shovelnose sturgeon	☐	☑	Yellow perch
☐	☐	Creek chub	☑	☑	Mountain whitefish	☐	☐	Sicklefin chub			
☑	☑	Emerald shiner	☐	☐	Northern pike	☑	☑	Smallmouth bass			
☑	☑	Fathead minnow	☐	☐	Northern plains killifish	☐	☐	Smallmouth buffalo			

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	256.7	146.5	6.6%
Rip Rap Bottom	319.3	143.7	6.5%
Rip Rap Margin	191.5	100.1	4.5%
Bluff Pool	15.4	5.2	0.2%
Terrace Pool	34.6	35.2	1.6%
Secondary Channel	149.0	64.9	2.9%
Secondary Channel (Seasonal)	436.3	259.2	11.7%
Channel Crossover	259.7	175.9	7.9%
Point Bar		131.6	5.9%
Side Bar		86.8	3.9%
Mid-channel Bar		153.1	6.9%
Island	558.6	562.1	25.3%
Dry Channel		356.9	16.1%

AVIAN

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

Bird Species Observed in Reach/Region

Species of Concern | Potential Species of Concern

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

Yellowstone River Reach Narratives — Reach B10

County	Yellowstone	**Upstream River Mile**	318
Classification	PCM: Partially confined meandering	**Downstream River Mile**	310.8
General Location	Waco	**Length**	7.20 mi (11.59 km)
General Comments	Encroached		

Narrative Summary

Reach B10 is located in lower Yellowstone County and contains the Captain Clark Fishing Access Site. The Reach is 7.2 miles long and is a Partially Confined Meandering reach type, (PCM), indicating the presence of a primary meandering channel thread with substantial valley wall influence on the river. The Captain Clark Fishing Access Site is located in the middle of the reach.

There are about 1,150 feet of rock riprap and 800 feet of flow deflectors in the reach, which collectively armor about 3 percent of the total bankline. About one half of the armor is protecting the active railroad, and the other half is protecting agricultural land. High resolution 2011 imagery shows the complete flanking of the mapped flow deflectors since 2001. The river has since eroded over 100 feet of bank behind the flanked barbs, eroding into a series of old corrals. The barbs are readily visible in the river.

One abandoned side channel that is about 3,300 feet long at RM 315R appears to be very old, however has several crossings that currently form plugs along its course. The channel is still within the 5-year floodplain, so the plugs have likely affected its function as a flood channel, and perhaps historically as a seasonal channel. This historic side channel is located landward (south) of the Fishing Access Site, which is on an old island. The lower end of this old channel supports a high density of Russian olive.

Reach B10 has lost almost 5.5 miles of side channel length since 1950. In the uppermost portion of the reach, the main river channel flipped from the south side of the corridor to the north sometime between 1976 and 2001, progressively abandoning a mile long channel and focusing the river into a single thread that flows along the north valley bluff line. This is where the flow deflectors described above have been flanked. This pattern has been common all through the reach; major secondary channels from the 1950s have been abandoned and the river has shifted to much more of a single thread meandering river. Some of the 1950's channels have potentially been blocked, and others appear to have been passively abandoned.

On the south side of the river at RM 312.5, the rail line currently isolates about 42 acres of historic 100-year floodplain. The river is currently against the rail line at this location, so that the separation between the river and the isolated remnant is only about 200 feet. This area is also adjacent to about 20 acres of mapped emergent wetland.

Overall, land uses in reach B10 are primarily agricultural, with about 860 acres of flood irrigated land mapped as of 2011. About one third of that irrigated acreage is within the CMZ. The railroad has encroached into 19 acres of the CMZ. In total, just under 7 percent of the CMZ has been restricted, and all of that restriction is due to bank armor protecting the rail line.

The modern 5-year floodplain contains about 72acres of flood-irrigated ground. Reach B10 also supports almost 40 acres of mapped wetlands per valley mile, which is a relatively high density for the corridor.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 30,200 cfs to 24,500 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,070 cfs to 2,090 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B10 include:
•Active and passive abandonment of over five miles of anabranching channel length since 1950
•Bank armor flanking associated with flow consolidation into single thread.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B10 include:
•Removal of flanked flow deflectors at RM 318
•Side channel reactivation throughout reach
•Floodplain reconnection at Rm 312.5R
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	126.8	46.4

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	30,200	55,500	68,100	75,700	91,000	97,200	111,000	3,070	3,846
Regulated	24,500	49,400	62,400	70,400	86,900	93,600	108,800	2,090	2,227
% Change	-18.87%	-10.99%	-8.37%	-7.00%	-4.51%	-3.70%	-1.98%	-31.92%	-42.10%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	NARA	July 9-27, 1950	B/W		6214500	29500
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	7/29/1996 - 8/26/96 - 8/19/96	B/W		6214500	10400
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	14-May-04	Color	1:15,840	6214500	7010
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2009	NAIP	6/29/2009	Color	1-meter pixels	6214500	26200
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/16/2011	Color	1-meter pixels	6214500	36000
2013	NAIP	06/16/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	1,153	1.5%	1,153	1.5%	0
	Flow Deflectors	194	0.3%	194	0.3%	0
	Between Flow Deflectors	613	0.8%	613	0.8%	0
	Feature Type Totals	**1,960**	**2.6%**	**1,960**	**2.6%**	**0**
Floodplain Control						
	Transportation Encroachment	6,439	8.5%	6,439	8.5%	0
	Feature Type Totals	**6,439**	**8.5%**	**6,439**	**8.5%**	**0**
	Reach Totals	**8,399**	**11.0%**	**8,399**	**11.0%**	**0**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	0	0	895	0	0	0	0	0
Rock RipRap	0	0	0	0	0	656	0	0
Totals	**0**	**0**	**895**	**0**	**0**	**656**	**0**	**0**

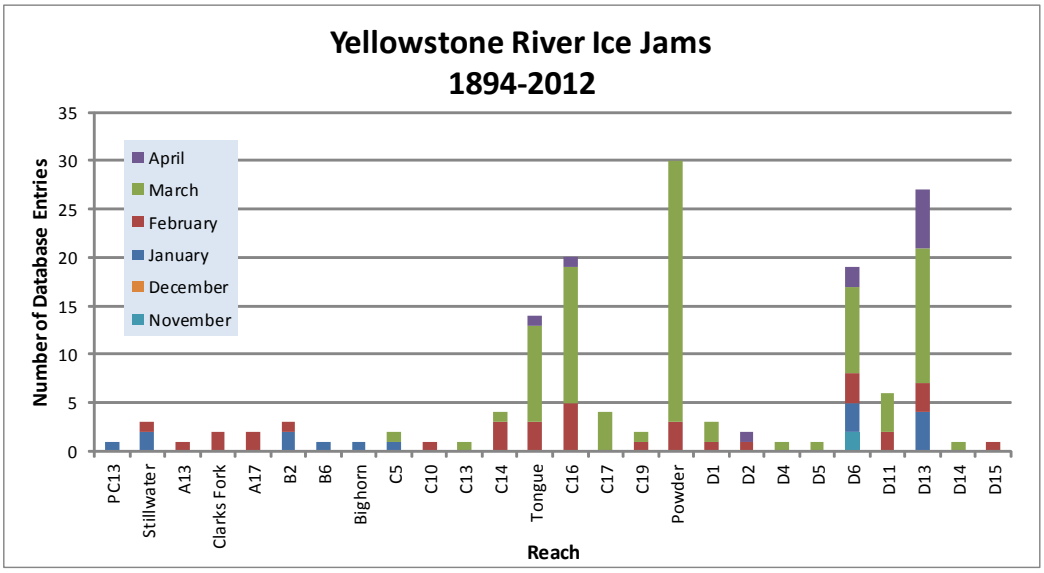
Bankline/Floodplain Inventory: Time Series

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

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Stream Stabilization							
	Rock RipRap	1,048	1,956	2,172	2,172	2,172	2,172
	Flow Deflector	0	0	0	742	2,131	2,131
	Concrete RipRap	0	0	255	255	255	255
	Totals	**1,048**	**1,956**	**2,427**	**3,169**	**4,558**	**4,558**
Transportation Encroachment							
	Railroad	20,661	20,661	20,661	20,661	20,661	20,661
	Interstate	0	9,540	9,540	9,540	9,540	9,540
	County Road	19,403	19,403	19,403	19,403	19,403	19,403
	Totals	**40,064**	**49,605**	**49,605**	**49,605**	**49,605**	**49,605**

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	36,593	55,863	2.53	1950 to 1976:	-24.62%
1976	39,622	35,840	1.90	1976 to 1995:	12.29%
1995	37,698	42,926	2.14	1995 to 2001:	-19.85%
2001	38,094	27,208	1.71	1950 to 2001:	-32.15%
Change 1950 - 2001	**1,501**	**-28,655**	**-0.81**		

Length of Side Channels Blocked

Pre-1950s (ft)	3,344
Post-1950s (ft)	0

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	112	6.5%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1595		1648	
Total Floodplain Area (Ac)	1707		1850	
Total Isolated (Ac)	**112**	**6.5%**	**202**	**18.7%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	72	0	0	**72**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
668	1,336	2,332	164	7%	50	0	0%

2011 Restricted Migration Area Summary

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

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	159	6.7%
RipRap/Flow Deflectors			
	Other Infrastructure	5	0.2%
	Totals	**164**	**6.9%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
323.6	0.0	0.0	0.0	18.7

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	44	54	56	58	0.8%	1.0%	1.0%	1.1%
	Totals	**44**	**54**	**56**	**58**	**0.8%**	**1.0%**	**1.0%**	**1.1%**
Agricultural Land									
	Non-Irrigated	3,565	3,487	3,387	3,406	64.6%	63.2%	61.3%	61.7%
	Irrigated	637	749	909	858	11.5%	13.6%	16.5%	15.5%
	Totals	**4,202**	**4,236**	**4,296**	**4,264**	**76.1%**	**76.7%**	**77.8%**	**77.2%**
Channel									
	Channel	1,220	1,060	992	1,021	22.1%	19.2%	18.0%	18.5%
	Totals	**1,220**	**1,060**	**992**	**1,021**	**22.1%**	**19.2%**	**18.0%**	**18.5%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	2	8	8	0.0%	0.0%	0.1%	0.1%
	Totals	**0**	**2**	**8**	**8**	**0.0%**	**0.0%**	**0.1%**	**0.1%**
Transportation									
	Public Road	18	41	41	41	0.3%	0.7%	0.7%	0.7%
	Interstate	0	93	93	93	0.0%	1.7%	1.7%	1.7%
	Railroad	36	36	36	36	0.7%	0.7%	0.7%	0.7%
	Totals	**55**	**170**	**170**	**170**	**1.0%**	**3.1%**	**3.1%**	**3.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	637	749	909	858	15.2%	17.7%	21.2%	20.1%	2.5%	3.5%	-1.0%	5.0%
	Totals	**637**	**749**	**909**	**858**	**15.2%**	**17.7%**	**21.2%**	**20.1%**	**2.5%**	**3.5%**	**-1.0%**	**5.0%**

Non-Irrigated

Multi-Use	3,089	2,948	3,006	2,985	73.5%	69.6%	70.0%	70.0%	-3.9%	0.4%	0.0%	-3.5%
Hay/Pasture	476	539	381	421	11.3%	12.7%	8.9%	9.9%	1.4%	-3.9%	1.0%	-1.5%
Totals	**3,565**	**3,487**	**3,387**	**3,406**	**84.8%**	**82.3%**	**78.8%**	**79.9%**	**-2.5%**	**-3.5%**	**1.0%**	**-5.0%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.0	0.2	0.4	0.0	1.4	1.8	0.8	1.6	5.3
Max	54.3	35.8	115.1	64.0	30.8	75.1	138.5	76.0	45.7
Average	8.1	7.8	19.2	15.8	12.8	27.3	16.2	19.0	17.5
Sum	276.3	321.3	422.2	427.9	166.8	327.2	226.1	304.3	157.7

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	230.5
Channel to Riparian (acres)	237.2
Riparian Encroachment (acres)	**6.7**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	244.2
1950s Floodplain Mapped as 2011 Channel (Ac)	170.4
Total Recruitment (1950s to 2011)(Ac)	**414.5**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	19.7	113.2	106.4	0.0	**239.3**
Acres/Valley Mile	3.3	18.9	17.8	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	38.82	1.47%	5.14	0.78	10.00	3.84

FISHERIES SUMMARY

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

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

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

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

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	125.7	63.8	6.4%
Rip Rap Bottom	50.1	24.1	2.4%
Bluff Pool	329.4	145.6	14.7%
Secondary Channel (Seasonal)	163.8	145.2	14.6%
Channel Crossover	100.5	79.4	8.0%
Point Bar		54.4	5.5%
Side Bar		41.1	4.1%
Mid-channel Bar		62.7	6.3%
Island	222.3	222.3	22.4%
Dry Channel		153.0	15.4%

AVIAN

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

Bird Species Observed in Reach/Region

Species of Concern | Potential Species of Concern

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Yellowstone	**Upstream River Mile**	310.8
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	302.7
General Location	To Custer Bridge	**Length**	8.10 mi (13.04 km)
General Comments	To Custer Bridge		

Narrative Summary

Reach B11 is located in lower Yellowstone County. The Reach is 8.1 miles long and is a Partially Confined Anabranching reach type, (PCA), indicating the presence of forested islands with substantial valley wall influence on the river. Custer Bridge and the town of Bighorn are at the lower end of the reach.

There are about 2,600 feet of rock riprap and 1,200 feet of flow deflectors in the reach, which collectively armors about 4 percent of the total bankline. All of the armor is protecting agricultural land, both irrigated and non-irrigated. Most of the rock riprap was built between 1950 and 1976, whereas the flow deflectors were built between 1995 and 2001.

One side channel that is about 1,000 feet long at RM 305R appears to have been blocked as a seasonal channel by three different plugs that were all in place in 1950. Hydraulic modeling results show that under undeveloped conditions, the channel conveyed water at a 2-year discharge, but now it doesn't convey flow at the 5-year discharge. The blocked channel now has dense stands of Russian olive on its lower end.

Since 1950, the bankfull area of the channel has increased by about 60 acres in Reach B11 indicating some enlargement of the main channel between 1950 and 2001. This is interesting because there was also a net increase in riparian area due to erosional processes of about 75 acres, which may appear contradictory. In reviewing the GIS data, it is apparent that much of the channel migration in Reach B11 was through unvegetated farm fields such that the channel was able to enlarge, and the area created by the migration was then colonized by riparian vegetation, resulting in a net gain in riparian area, along with an increase in overall channel size. The total riparian recruitment acreage in the reach was 483 acres; 334 of those acres of recruitment were in 1950s channel areas, and 149 acres of eroded floodplain have been colonized by woody riparian species. The increase in riparian area is most evidenced by riparian shrub, which increased from 219 acres in 1950 to 462 acres in 2001. Reach B11 consequently has a robust riparian corridor with active recruitment associated with channel migration.

Reach B11 experienced a major avulsion between 1976 and 1002, when the river jumped about 1,600 feet to the northwest between RM 305 and RM 306, relocating into a relatively small developing side channel. The avulsed channel has since been migrating back to the southeast, creating a large sediment deposit downstream at RM 305 where the river corridor is tightly confined by the valley wall to the northwest and bank armored fields to the southeast. This section of river appears quite unstable.

Most of the floodplain isolation has been related to more frequent flooding; whereas 2 percent of the 100-year floodplain has become isolated due to human development, about 17 percent of the 5-year floodplain is no longer inundated at that frequency. Much of the loss of 5-year floodplain was in the blocked channel at RM 305R described above. The 100-year isolated floodplain is behind the active rail line and Interstate about 1,000 feet south of the river at RM 308.5R. Emergent wetlands have been mapped in this isolated floodplain area, which is about 21 acres in size. Hydraulic modeling indicates that this area would also be inundated at a 5-year event, making it a good potential candidate for restoring floodplain connectivity through the rail line and frontage road, or for simple wetland restoration.

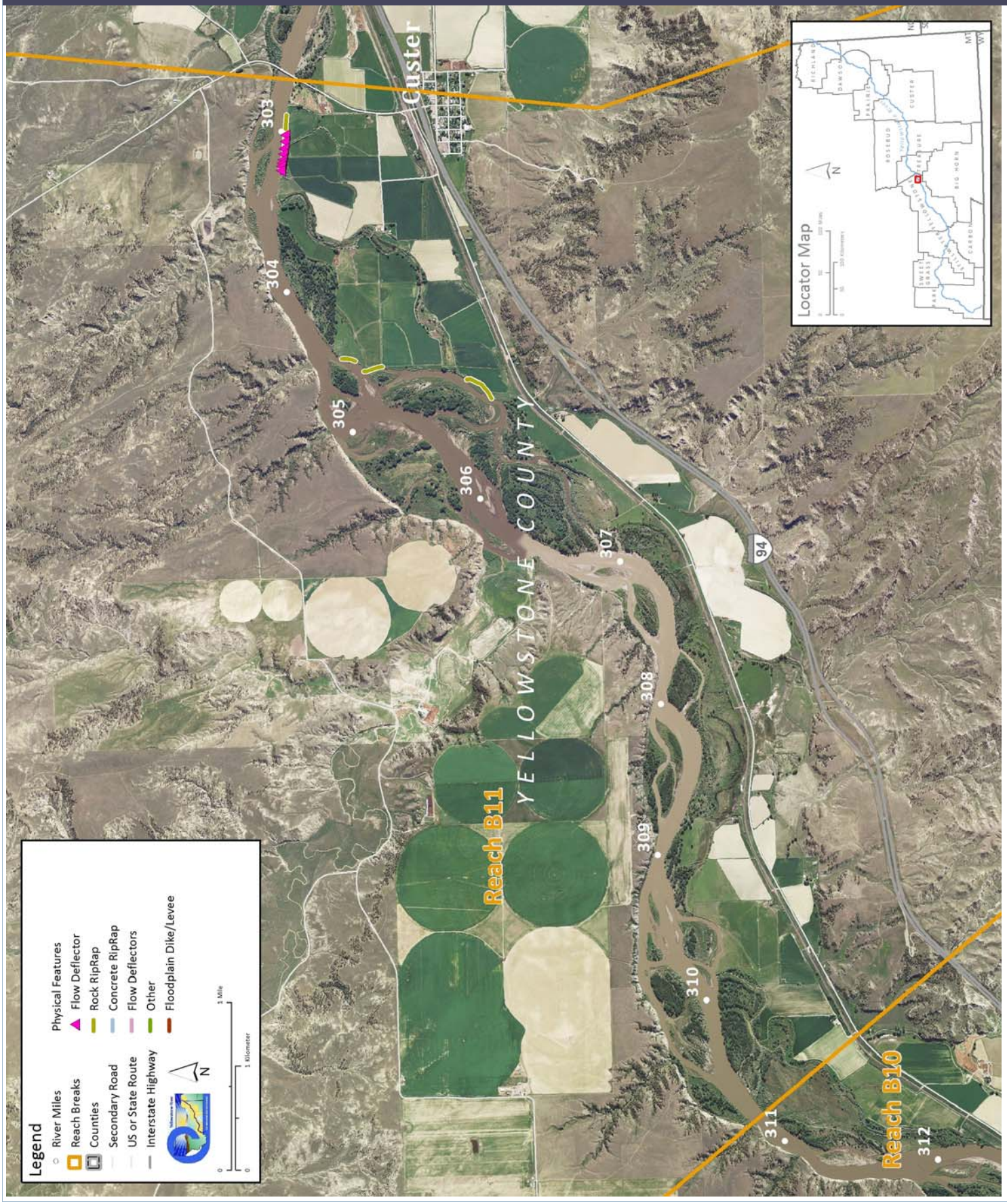
The mapped land uses in Reach B11 indicate that flood irrigation is the dominant land use, with about 1,500 acres of ground in flood irrigation and 100 in pivot. The town of Bighorn contributes to about 70 acres of urban/exurban development, and the proximity of the rail line to the river corridor is evidenced by 191 acres of transportation footprint. The most common developed land use in the Channel Migration Zone (CMZ) is flood irrigation (431 acres). About 17 percent of the CMZ has been isolated due to physical features such as bank armor and floodplain dikes, and most of that is riprap protection against irrigated lands (11 percent of CMZ). Most of these restrictions are in the lower reach near the town of Bighorn.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 30,200 cfs to 24,500 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,080 cfs to 2,100 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B11 include:
•Side channel blockage prior to 1950
•Channel instability caused by avulsion at RM 305

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B11 include:
•Side channel reactivation at RM 305R
•Floodplain reconnection at Rm 308.5R
•Russian olive removal
•Channel Migration Zone (CMZ) management due to extent of CMZ restricted (17 percent)

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	118.7	53.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	30,200	55,500	68,100	75,700	91,000	97,200	111,000	3,080	3,846
Regulated	24,500	49,400	62,400	70,400	86,900	93,600	108,800	2,100	2,227
% Change	-18.87%	-10.99%	-8.37%	-7.00%	-4.51%	-3.70%	-1.98%	-31.82%	-42.10%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	NARA	July 9-27, 1950	B/W		6214500	29500
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	19-Aug-96	B/W		6214500	5320
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	14-May-04	Color	1:15,840	6214500	7010
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2009	NAIP	6/29/2009	Color	1-meter pixels	6214500	26200
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/16/2011	Color	1-meter pixels	6214500	36000
2013	NAIP	06/16/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	2,570	3.0%	2,570	3.0%	0
	Flow Deflectors	395	0.5%	395	0.5%	0
	Between Flow Deflectors	774	0.9%	774	0.9%	0
	Feature Type Totals	**3,740**	**4.4%**	**3,740**	**4.4%**	**0**
	Reach Totals	**3,740**	**4.4%**	**3,740**	**4.4%**	**0**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	1,168	0	0	0	0	0	0	0
Rock RipRap	597	1,975	0	0	0	0	0	0
Totals	**1,765**	**1,975**	**0**	**0**	**0**	**0**	**0**	**0**

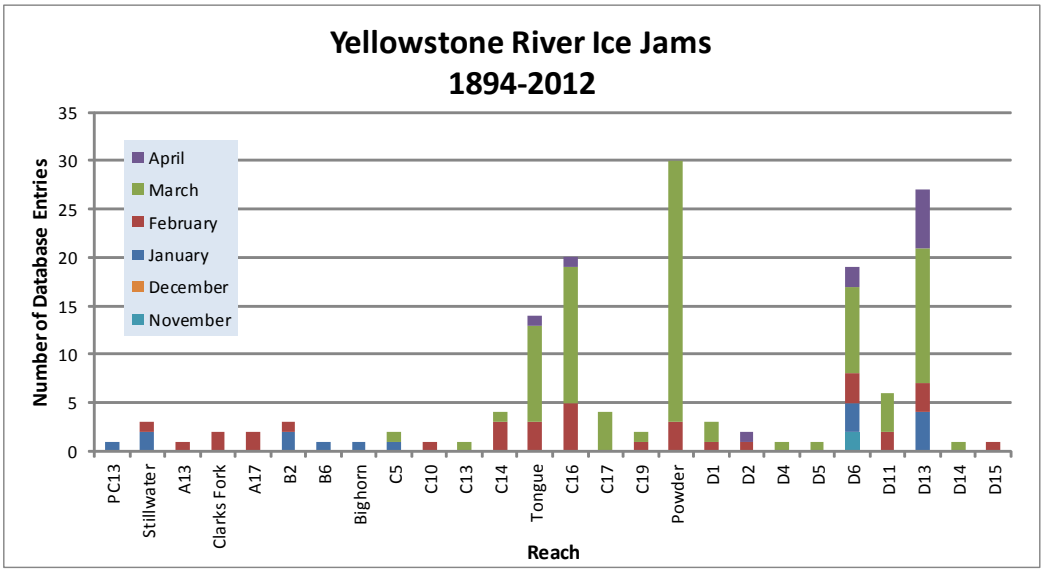
Bankline/Floodplain Inventory: Time Series

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

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Other Off Channel							
	Floodplain Dike/Levee	2,005	2,005	2,005	2,005	2,005	2,005
	Totals	**2,005**	**2,005**	**2,005**	**2,005**	**2,005**	**2,005**
Stream Stabilization							
	Rock RipRap	0	4,133	5,643	6,103	6,103	6,103
	Flow Deflector	0	0	0	939	939	939
	Totals	**0**	**4,133**	**5,643**	**7,042**	**7,042**	**7,042**
Transportation Encroachment							
	Railroad	12,691	12,691	12,691	12,691	12,691	12,691
	County Road	11,967	11,967	11,967	11,967	11,967	11,967
	Bridge Approach	3,362	3,362	3,362	3,362	3,362	3,362
	Totals	**28,020**	**28,020**	**28,020**	**28,020**	**28,020**	**28,020**

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	43,911	64,157	2.46	1950 to 1976:	-3.81%
1976	44,567	60,938	2.37	1976 to 1995:	5.48%
1995	42,397	63,466	2.50	1995 to 2001:	3.63%
2001	42,826	67,992	2.59	1950 to 2001:	5.14%
Change 1950 - 2001	**-1,085**	**3,834**	**0.13**		

Length of Side Channels Blocked

Pre-1950s (ft)	1,002
Post-1950s (ft)	0

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	33	1.9%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1743		1989	
Total Floodplain Area (Ac)	1777		2195	
Total Isolated (Ac)	**33**	**1.9%**	**206**	**16.9%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	74	0	0	**74**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
607	1,214	2,820	309	11%	228	203	89%

2011 Restricted Migration Area Summary

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	98	3.2%
	Public Road	1	0.0%
RipRap/Flow Deflectors			
	Irrigated	88	2.9%
RipRap			
	Irrigated	325	10.7%
	Totals	**511**	**16.8%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
431.0	0.0	0.0	1.0	24.5

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	54	62	70	74	0.8%	0.9%	1.0%	1.1%
	Totals	**54**	**62**	**70**	**74**	**0.8%**	**0.9%**	**1.0%**	**1.1%**
Agricultural Land									
	Non-Irrigated	3,927	3,508	3,334	3,348	57.8%	51.6%	49.1%	49.3%
	Irrigated	1,190	1,538	1,685	1,592	17.5%	22.6%	24.8%	23.4%
	Totals	**5,117**	**5,046**	**5,018**	**4,941**	**75.3%**	**74.3%**	**73.9%**	**72.7%**
Channel									
	Channel	1,462	1,444	1,456	1,516	21.5%	21.3%	21.4%	22.3%
	Totals	**1,462**	**1,444**	**1,456**	**1,516**	**21.5%**	**21.3%**	**21.4%**	**22.3%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	6	20	0.0%	0.0%	0.1%	0.3%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	2	4	5	5	0.0%	0.1%	0.1%	0.1%
	Totals	**2**	**4**	**11**	**25**	**0.0%**	**0.1%**	**0.2%**	**0.4%**
Transportation									
	Public Road	49	48	48	48	0.7%	0.7%	0.7%	0.7%
	Interstate	0	104	104	104	0.0%	1.5%	1.5%	1.5%
	Railroad	39	39	39	39	0.6%	0.6%	0.6%	0.6%
	Totals	**88**	**191**	**191**	**191**	**1.3%**	**2.8%**	**2.8%**	**2.8%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	26	26	26	26	0.4%	0.4%	0.4%	0.4%
	Urban Commercial	21	19	19	19	0.3%	0.3%	0.3%	0.3%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	21	0	0	0	0.3%	0.0%	0.0%	0.0%
	Totals	**68**	**45**	**45**	**45**	**1.0%**	**0.7%**	**0.7%**	**0.7%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	37	99	102	0.0%	0.7%	2.0%	2.1%	0.7%	1.2%	0.1%	2.1%
	Flood	1,190	1,501	1,586	1,491	23.3%	29.8%	31.6%	30.2%	6.5%	1.8%	-1.4%	6.9%
	Totals	**1,190**	**1,538**	**1,685**	**1,592**	**23.3%**	**30.5%**	**33.6%**	**32.2%**	**7.2%**	**3.1%**	**-1.3%**	**9.0%**

Non-Irrigated

Multi-Use	3,091	3,010	3,110	2,772	60.4%	59.6%	62.0%	56.1%	-0.8%	2.3%	-5.9%	-4.3%
Hay/Pasture	836	498	223	577	16.3%	9.9%	4.5%	11.7%	-6.5%	-5.4%	7.2%	-4.7%
Totals	**3,927**	**3,508**	**3,334**	**3,348**	**76.7%**	**69.5%**	**66.4%**	**67.8%**	**-7.2%**	**-3.1%**	**1.3%**	**-9.0%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.4	0.2	0.5	0.6	0.6	1.1	1.3	6.5	5.0
Max	31.0	34.1	85.4	122.4	92.9	86.6	51.4	27.6	53.5
Average	6.5	8.4	14.9	18.0	19.0	28.1	8.9	14.2	21.5
Sum	219.3	319.5	462.4	504.7	531.0	422.1	169.4	155.7	215.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	255.2
Channel to Riparian (acres)	329.7
Riparian Encroachment (acres)	**74.5**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	334.4
1950s Floodplain Mapped as 2011 Channel (Ac)	149.3
Total Recruitment (1950s to 2011)(Ac)	**483.7**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	17.6	160.7	43.0	0.0	**221.4**
Acres/Valley Mile	2.4	21.8	5.8	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	30.62	0.85%	1.45	3.23	12.87	2.88

FISHERIES SUMMARY

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

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

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

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

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	286.3	192.2	13.2%
Rip Rap Bottom	17.0	12.7	0.9%
Bluff Pool	89.0	31.0	2.1%
Secondary Channel	49.8	33.7	2.3%
Secondary Channel (Seasonal)	384.2	176.3	12.1%
Channel Crossover	150.0	115.4	7.9%
Point Bar		37.3	2.6%
Side Bar		99.9	6.9%
Mid-channel Bar		75.3	5.2%
Island	479.7	479.7	32.9%
Dry Channel		202.5	13.9%

AVIAN

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Yellowstone	**Upstream River Mile**	302.7
Classification	UA: Unconfined anabranching	**Downstream River Mile**	298.1
General Location	To Bighorn River confluence	**Length**	4.60 mi (7.40 km)
General Comments	to Bighorn River confluence		

Narrative Summary

Reach B12 is located in lowermost Yellowstone County and extends to the mouth of the Bighorn River. The Reach is 4.6 miles long and is an Unconfined Anabranching reach type, (UA), indicating the presence of forested islands with minimal valley wall influence on the river. These reach types tend to be the most dynamic of all reach types, with typically high rates of bank migration.

There are about 7,800 feet of rock riprap in the reach, which collectively armors about 16 percent of the total bankline. Most of the armor (7,700 feet) is protecting the rail line, with the remainder protecting non-irrigated agricultural land. At two locations (RM 301.5 and RM 299), the river is flowing along bank armor that is right on the railroad prism. One segment of bank armor right at the Bighorn River confluence is actively flanking and will likely be eroded out shortly. Most of the rock riprap was in place in 1950. About 3 miles of transportation encroachment due to the railroad was mapped in the reach.

No blocked side channels have been mapped in Reach B12.

Floodplain turnover rates have dropped in this reach, from 1.9 acres/year/valley mile between 1950 and 1976 to 1.3 acres/year/valley mile between 1976 and 2001. Between 1950 and 2001, there was a total of 214 acres of riparian recruitment in the reach, most of which was colonization of area that was channel in 1950.

Whereas 9 percent of the 100-year floodplain has become isolated due to human development, about 21 percent of the 5-year floodplain is no longer inundated at that frequency. All of the 100-year floodplain isolation is due to the railroad. These areas are very proximal to the river at RM 299 and 302, and could potentially be considered for floodplain and/or wetland restoration.

Land use is dominated by agriculture, with 137 acres of pivot irrigation development since 1950. Almost 50 of those acres of pivot are within the Channel Migration Zone (CMZ). Almost 9 percent of the Channel Migration Zone (CMZ) has been restricted, and the vast majority of that restriction is due to rock riprap protection of the railroad (8 percent).

Reach B12 supports 144 acres of wetland, which at over 35 acres per valley mile is a relatively high concentration of wetlands on the river. There are also 33 acres of mapped Russian olive.

Contrary to most other Reaches, Reach B11 has seen an increase in forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 33 acres per valley mile of such forest, and that number increased to 36 acres per valley mile by 2001.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 30,200 cfs to 24,500 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,090 cfs to 2,100 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B12 include:
•Active flanking of bank armor at mouth of Bighorn River
•Channel instability caused by avulsion at RM 305

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B12 include:
•Bank armor maintenance where active flanking is occurring at mouth of Bighorn River at RM 298.3R
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	114.1	61.7

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	30,200	55,500	68,100	75,700	91,000	97,200	111,000	3,090	3,846
Regulated	24,500	49,400	62,400	70,400	86,900	93,600	108,800	2,100	2,227
% Change	-18.87%	-10.99%	-8.37%	-7.00%	-4.51%	-3.70%	-1.98%	-32.04%	-42.10%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	NARA	July 9-27, 1950	B/W		6214500	29500
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	8/19/96 - 8/8/96	B/W		6214500	5320
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	14-May-04	Color	1:15,840	6214500	7010
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2005	NAIP	07/13/2005	color	1-meter pixels	6214500	11100
2009	NAIP	6/29/2009	Color	1-meter pixels	6214500	26200
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/20/2011	Color	1-meter pixels	6214500	30500
2011	NAIP	7/16/2011	Color	1-meter pixels	6214500	36000
2013	NAIP	06/16/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	7,778	16.2%	7,778	16.2%	0
	Feature Type Totals	**7,778**	**16.2%**	**7,778**	**16.2%**	**0**
Floodplain Control						
	Transportation Encroachment	15,641	32.5%	15,641	32.5%	0
	Feature Type Totals	**15,641**	**32.5%**	**15,641**	**32.5%**	**0**
	Reach Totals	**23,420**	**48.7%**	**23,420**	**48.7%**	**0**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	0	1,227	0	0	0	7,698	0	0
Totals	**0**	**1,227**	**0**	**0**	**0**	**7,698**	**0**	**0**

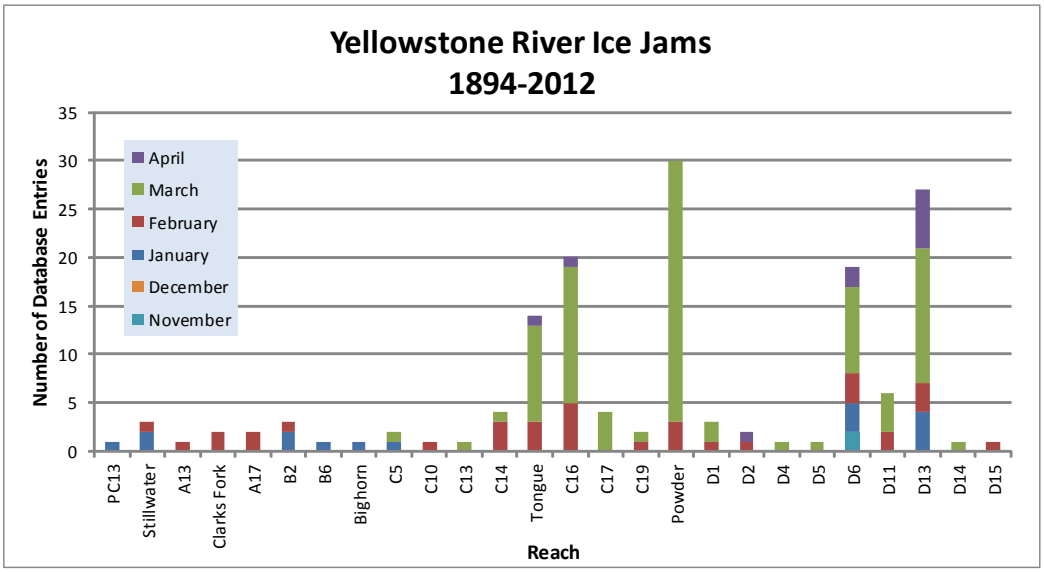
Bankline/Floodplain Inventory: Time Series

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

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Other Off Channel							
	Floodplain Dike/Levee	987	987	987	987	987	987
	Totals	**987**	**987**	**987**	**987**	**987**	**987**
Stream Stabilization							
	Rock RipRap	7,346	8,666	9,392	10,182	10,182	10,182
	Totals	**7,346**	**8,666**	**9,392**	**10,182**	**10,182**	**10,182**
Transportation Encroachment							
	Railroad	15,096	15,096	15,096	15,096	15,096	15,096
	Interstate	0	3,548	3,548	3,548	3,548	3,548
	Bridge Approach	562	562	562	562	562	562
	Totals	**15,658**	**19,206**	**19,206**	**19,206**	**19,206**	**19,206**

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	23,947	47,793	3.00	1950 to 1976:	-6.81%
1976	23,530	42,157	2.79	1976 to 1995:	1.36%
1995	23,760	43,470	2.83	1995 to 2001:	0.80%
2001	24,028	44,502	2.85	1950 to 2001:	-4.80%
Change 1950 - 2001	**81**	**-3,291**	**-0.14**		

Length of Side Channels Blocked

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

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	90	8.7%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	937		1097	
Total Floodplain Area (Ac)	1027		1239	
Total Isolated (Ac)	**90**	**8.7%**	**142**	**20.7%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	6	**6**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
381	761	1,654	147	9%	17	0	0%

2011 Restricted Migration Area Summary

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

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	12	0.7%
RipRap			
	Railroad	134	8.0%
	Totals	**147**	**8.8%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
102.9	0.0	48.5	0.0	19.4

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	11	21	31	43	0.3%	0.5%	0.8%	1.1%
	Totals	**11**	**21**	**31**	**43**	**0.3%**	**0.5%**	**0.8%**	**1.1%**
Agricultural Land									
	Non-Irrigated	2,487	2,327	2,198	2,112	61.8%	57.8%	54.6%	52.5%
	Irrigated	498	522	676	693	12.4%	13.0%	16.8%	17.2%
	Totals	**2,985**	**2,848**	**2,874**	**2,805**	**74.2%**	**70.8%**	**71.4%**	**69.7%**
Channel									
	Channel	955	1,011	976	1,033	23.7%	25.1%	24.2%	25.7%
	Totals	**955**	**1,011**	**976**	**1,033**	**23.7%**	**25.1%**	**24.2%**	**25.7%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	35	39	39	39	0.9%	1.0%	1.0%	1.0%
	Interstate	0	65	65	65	0.0%	1.6%	1.6%	1.6%
	Railroad	25	25	25	25	0.6%	0.6%	0.6%	0.6%
	Totals	**60**	**130**	**130**	**130**	**1.5%**	**3.2%**	**3.2%**	**3.2%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	4	4	4	4	0.1%	0.1%	0.1%	0.1%
	Urban Commercial	11	11	11	11	0.3%	0.3%	0.3%	0.3%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**15**	**15**	**15**	**15**	**0.4%**	**0.4%**	**0.4%**	**0.4%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	15	137	0.0%	0.0%	0.5%	4.9%	0.0%	0.5%	4.4%	4.9%
	Flood	498	522	661	556	16.7%	18.3%	23.0%	19.8%	1.6%	4.7%	-3.2%	3.1%
	Totals	**498**	**522**	**676**	**693**	**16.7%**	**18.3%**	**23.5%**	**24.7%**	**1.6%**	**5.2%**	**1.2%**	**8.0%**

Non-Irrigated

Multi-Use	2,053	2,033	2,029	1,944	68.8%	71.4%	70.6%	69.3%	2.6%	-0.8%	-1.3%	0.5%
Hay/Pasture	434	294	170	168	14.5%	10.3%	5.9%	6.0%	-4.2%	-4.4%	0.1%	-8.5%
Totals	**2,487**	**2,327**	**2,198**	**2,112**	**83.3%**	**81.7%**	**76.5%**	**75.3%**	**-1.6%**	**-5.2%**	**-1.2%**	**-8.0%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.5	0.7	0.6	3.2	0.8	0.6	0.0	0.5	0.3
Max	62.3	49.2	66.6	91.5	131.1	56.8	30.5	47.0	112.3
Average	10.4	7.7	13.9	25.2	30.7	17.3	9.7	9.0	26.0
Sum	198.4	199.8	333.3	226.5	276.3	190.5	115.9	126.4	182.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	138.5
Channel to Riparian (acres)	206.1
Riparian Encroachment (acres)	**67.6**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	197.2
1950s Floodplain Mapped as 2011 Channel (Ac)	17.3
Total Recruitment (1950s to 2011)(Ac)	**214.5**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	5.6	104.4	34.3	0.0	**144.3**
Acres/Valley Mile	1.5	27.8	9.1	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	32.54	1.56%	0.42	1.66	12.52	10.02

FISHERIES SUMMARY

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

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

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

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

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	179.4	99.9	10.2%
Rip Rap Bottom	64.0	10.2	1.0%
Secondary Channel	31.8	19.4	2.0%
Secondary Channel (Seasonal)	228.1	144.2	14.8%
Channel Crossover	60.9	54.1	5.5%
Point Bar		13.5	1.4%
Side Bar		58.4	6.0%
Mid-channel Bar		37.4	3.8%
Island	423.1	423.1	43.4%
Dry Channel		115.7	11.9%

AVIAN

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

Yellowstone River Reach Narratives — Reach B2

County	Yellowstone	**Upstream River Mile**	368.3
Classification	PCB: Partially confined braided	**Downstream River Mile**	362.2
General Location	Billlings	**Length**	6.10 mi (9.82 km)
General Comments	Billlings; WAI Reach E		

Narrative Summary

Reach B2 is 6.1 miles long and located in Billings. The reach extends from the rimrock bluffs south of town, under the I-90 Bridge, to the refinery area at Lockwood. It is a Partially Confined Braided (PCB) reach type indicating some influence of the bluff line on the river coupled by extensive open gravel bars and low flow channels. Reach B2 is extensively urbanized, with floodplain dikes, industrial and urban/exurban development, pipeline crossings, and bridges throughout the reach. Flow alterations in this reach have been substantial; the mean annual flood has dropped an estimated 17 percent due to human influences, and summer low flows have dropped by 42 percent.

In total there are 21,700 feet of bank armor in Reach B2, which equates to 4.1 miles of bank armor in a 6 mile long reach of river. Concrete riprap is the most prevalent type of armor, with about three miles present in 2011. There is almost a mile of rock riprap and a few flow deflectors. There are also over three miles of floodplain dikes mapped in the reach.

Since 1950, 6,566 feet of side channels have been blocked by dikes. These blocked side channels are in highly urbanized areas upstream of the I-90 Bridge and at the water treatment plant downstream.

The primary land use in the reach is urban/exurban development. A total of 620 acres of the historic 100-year floodplain has become isolated from the river, which is 41 percent of the total 100-year floodplain footprint. Most of the 100-year floodplain isolation is due to the Interstate Highway Embankment. Approximately 21 percent of the Channel Migration Zone has become restricted due to physical features, most of which are riprap installed to protect urban/industrial land uses.

A total of three ice jams have been recorded in Reach B2. One of these jams occurred in February of 1996, and the other two in January of 1997. They all resulted in flooding and the January 3 1997 jam caused some evacuations. The jams were reported as forming upstream of the I-90 Bridge.

There are numerous pipeline crossings in Reach B2. At RM 367 two pipelines cross under the river. One is a crude oil pipeline owned by Beartooth Pipeline that is HDD (Horizontal Directionally Drilled). The other is a petroleum product pipeline owned by Phillips 66 that as of Fall 2012 was trenched, and according to the addendum to the Yellowstone River Pipeline Risk Assessment, had 4 to 10 feet of cover. Further downstream, there are seven pipelines listed in the Pipeline Risk Assessment Report at RM 365. Several of these pipelines are trenched as a bundle, with a reported minimum of two feet of cover.
About 25 acres of Russian olive have been mapped in Reach B2.

Reach B2 was sampled as part of the fisheries study. A total of 31 fish species were sampled in the reach and one of those species was Sauger, which has been identified by the Montana Natural Heritage Program as a Species of Concern (SOC).

Reach B2 was sampled as part of the avian study. The average species richness in Reach B2 was 7.0, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. Two bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were also found, the Ovenbird and the Plumbeous Vireo.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 23,700 cfs to 19,700 cfs, a drop of about 17 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,910 cfs to 2,000 cfs with human development, a reduction of 31 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,836 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B2 include:
•Extensive armoring with CMZ encroachment

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B2 include:
•Pipeline crossing management
•Russian olive removal

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	178.2	-3.9

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	23,700	44,200	54,500	60,800	73,500	78,600	90,100	2,910	3,846
Regulated	19,700	39,800	50,400	57,000	70,500	76,000	88,500	2,000	2,227
% Change	-16.88%	-9.95%	-7.52%	-6.25%	-4.08%	-3.31%	-1.78%	-31.27%	-42.10%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	5/15/1951 - 5/14/51	B/W	1:28,400	6214500	12000
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	23-Aug-96	B/W		6214500	4500
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	15-May-04	Color	1:15,840	6214500	5960
2005	NAIP	07/12/2005	color	1-meter pixels	6214500	12600
2005	NAIP	07/08/2005	color	1-meter pixels	6214500	11400
2009	NAIP	7/5/2009	Color	1-meter pixels	6214500	23800
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/24/2011	Color	1-meter pixels	6214500	22800
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Steel Retaining Wall	192	0.3%	192	0.3%	0
	Rock RipRap	3,501	5.4%	4,329	6.7%	828
	Flow Deflectors	0	0.0%	67	0.1%	67
	Concrete RipRap	17,283	26.8%	17,283	26.8%	0
	Between Flow Deflectors	0	0.0%	24	0.0%	24
	Feature Type Totals	**20,977**	**32.5%**	**21,895**	**34.0%**	**918**
Other In Channel						
	Bedrock Outcrop	208	0.3%	208	0.3%	0
	Feature Type Totals	**208**	**0.3%**	**208**	**0.3%**	**0**
Floodplain Control						
	Floodplain Dike/Levee	7,037	10.9%	7,037	10.9%	0
	Feature Type Totals	**7,037**	**10.9%**	**7,037**	**10.9%**	**0**
	Reach Totals	**28,223**	**43.8%**	**29,141**	**45.2%**	**918**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	0	315	2,647	328	656	328	13,002	0
Rock RipRap	689	928	0	0	715	0	1,217	0
Steel Retaining Wall	0	0	0	0	0	0	194	0
Totals	**689**	**1,243**	**2,647**	**328**	**1,371**	**328**	**14,412**	**0**

Bankline/Floodplain Inventory: Time Series

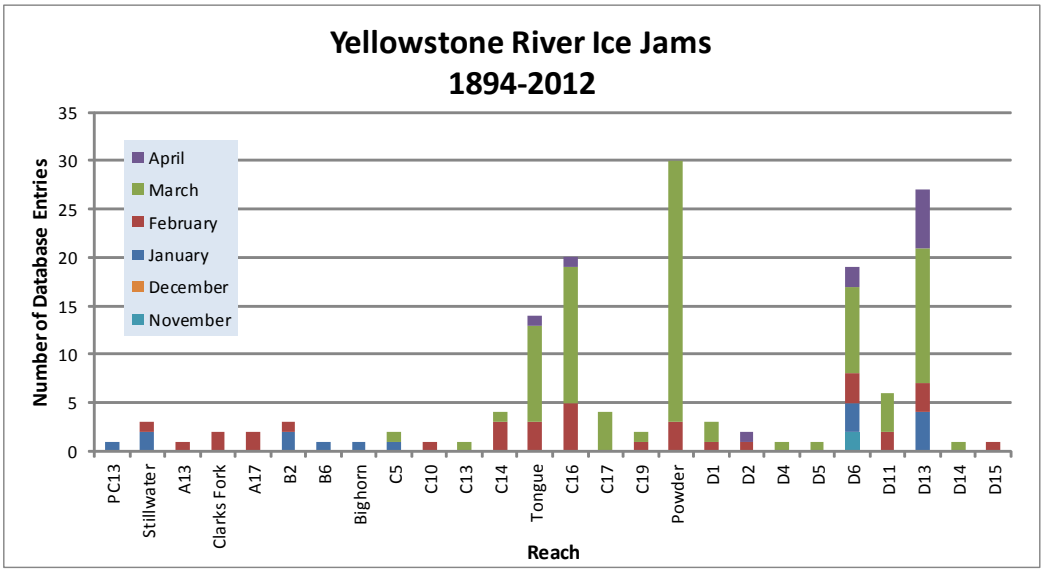
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	5,400	5,400	5,400	5,400	5,400	5,400
	Totals	**5,400**	**5,400**	**5,400**	**5,400**	**5,400**	**5,400**
Other							
	Floodplain Dike/Levee	12,435	17,523	17,523	17,523	17,523	17,523
	Totals	**12,435**	**17,523**	**17,523**	**17,523**	**17,523**	**17,523**
Other Off Channel							
	Floodplain Dike/Levee	0	3,468	3,468	3,468	3,468	3,468

	Floodplain Dike/Levee	0	0	757	757	757	757
	Totals	**0**	**3,468**	**4,225**	**4,225**	**4,225**	**4,225**
Stream Stabilization							
	Steel Retaining Wall	275	275	275	275	275	275
	Rock RipRap	1,100	2,973	3,758	3,758	3,758	3,758
	Concrete RipRap	5,062	15,933	18,005	18,005	18,005	18,005
	Totals	**6,437**	**19,182**	**22,039**	**22,039**	**22,039**	**22,039**
Transportation Encroachment							
	Railroad	1,491	1,491	1,491	1,491	1,491	1,491
	Other	3,322	3,960	1,861	1,861	1,861	1,861
	Interstate	0	10,378	10,378	10,378	10,378	10,378
	County Road	6,101	8,904	8,904	8,904	8,904	8,904
	Totals	**10,913**	**24,732**	**22,633**	**22,633**	**22,633**	**22,633**

ICE JAMS

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



Jam Date	Jam Type	River Mile	Damages
2/6/1996	NA	366	Flooded roadways
1/3/1997	NA	366	Flooding, evacuations
1/10/1997	NA	366	?

GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	31,111	29,288	1.94	1950 to 1976:	3.45%
1976	31,620	31,888	2.01	1976 to 1995:	-12.85%
1995	32,440	24,341	1.75	1995 to 2001:	1.21%
2001	32,233	24,867	1.77	1950 to 2001:	-8.75%
Change 1950 - 2001	**1,123**	**-4,421**	**-0.17**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	6,566

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	50	3.3%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	570	37.9%		
Total Not Isolated (Ac)	884		852	
Total Floodplain Area (Ac)	1504		910	
Total Isolated (Ac)	**620**	**41.2%**	**58**	**15.4%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	0	0	0	**0**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
245	490	1,118	251	22%	66	0	0%

2011 Restricted Migration Area Summary

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

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Urban Industrial	218	18.2%
Dike/Levee			
	Exurban Other	38	3.1%
	Totals	**256**	**21.3%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
0.0	0.0	0.0	276.5	10.3

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	33	17	9	17	0.8%	0.4%	0.2%	0.4%
	Totals	**33**	**17**	**9**	**17**	**0.8%**	**0.4%**	**0.2%**	**0.4%**
Agricultural Land									
	Non-Irrigated	1,988	1,545	1,358	1,066	45.8%	35.6%	31.3%	24.6%
	Irrigated	469	25	5	5	10.8%	0.6%	0.1%	0.1%
	Totals	**2,457**	**1,569**	**1,363**	**1,071**	**56.6%**	**36.2%**	**31.4%**	**24.7%**
Channel									
	Channel	725	702	612	629	16.7%	16.2%	14.1%	14.5%
	Totals	**725**	**702**	**612**	**629**	**16.7%**	**16.2%**	**14.1%**	**14.5%**
ExUrban									
	ExUrban Other	138	0	0	0	3.2%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	5	0	0	0	0.1%	0.0%	0.0%	0.0%
	ExUrban Industrial	30	0	0	0	0.7%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	145	15	0	0	3.3%	0.3%	0.0%	0.0%
	Totals	**318**	**15**	**0**	**0**	**7.3%**	**0.3%**	**0.0%**	**0.0%**
Transportation									
	Public Road	29	32	32	32	0.7%	0.7%	0.7%	0.7%
	Interstate	0	79	80	80	0.0%	1.8%	1.8%	1.8%
	Railroad	17	17	17	17	0.4%	0.4%	0.4%	0.4%
	Totals	**46**	**128**	**128**	**128**	**1.1%**	**2.9%**	**2.9%**	**2.9%**
Urban									
	Urban Other	13	58	90	98	0.3%	1.3%	2.1%	2.3%
	Urban Residential	117	455	472	713	2.7%	10.5%	10.9%	16.4%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	111	91	54	0.0%	2.6%	2.1%	1.2%
	Urban Industrial	630	1,285	1,575	1,631	14.5%	29.6%	36.3%	37.6%
	Totals	**760**	**1,910**	**2,228**	**2,495**	**17.5%**	**44.0%**	**51.3%**	**57.5%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	5	5	0.0%	0.0%	0.4%	0.5%	0.0%	0.4%	0.1%	0.5%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	469	25	0	0	19.1%	1.6%	0.0%	0.0%	-17.5%	-1.6%	0.0%	-19.1%
	Totals	**469**	**25**	**5**	**5**	**19.1%**	**1.6%**	**0.4%**	**0.5%**	**-17.5%**	**-1.2%**	**0.1%**	**-18.6%**

Non-Irrigated

Multi-Use	1,157	427	1,138	939	47.1%	27.2%	83.5%	87.6%	-19.8%	56.3%	4.1%	40.5%
Hay/Pasture	832	1,117	219	127	33.8%	71.2%	16.1%	11.9%	37.4%	-55.1%	-4.2%	-22.0%
Totals	**1,988**	**1,545**	**1,358**	**1,066**	**80.9%**	**98.4%**	**99.6%**	**99.5%**	**17.5%**	**1.2%**	**-0.1%**	**18.6%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	1.9	0.3	1.1	3.0	0.8	1.9	6.1	8.1	11.8
Max	87.6	41.0	40.7	59.3	90.7	125.5	87.3	58.1	43.3
Average	16.4	9.5	7.2	17.5	13.4	25.8	35.5	31.4	24.7
Sum	180.6	94.7	65.0	210.2	255.2	361.8	248.4	157.1	98.9

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	129.1
Channel to Riparian (acres)	91.8
Riparian Encroachment (acres)	**-37.2**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	105.2
1950s Floodplain Mapped as 2011 Channel (Ac)	42.7
Total Recruitment (1950s to 2011)(Ac)	**147.9**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	44.5	19.6	11.6	0.0	**75.7**
Acres/Valley Mile	8.0	3.5	2.1	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	24.62	3.18%	40.06	2.32	5.89	3.52

FISHERIES SUMMARY

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

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

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

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

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
☐	☑	Bigmouth buffalo	☑	☑	Flathead chub	☐	☐	Northern redbelly dace	☑	☑	Stonecat
☑	☑	Black bullhead	☐	☐	Freshwater drum	☐	☐	Pallid sturgeon	☐	☐	Sturgeon chub
☑	☑	Black crappie	☑	☑	Goldeye	☑	☑	Pumpkinseed	☑	☑	Sucker species
☐	☐	Blue sucker	☑	☑	Green sunfish	☑	☑	Rainbow trout	☐	☑	Sunfish species
☑	☑	Bluegill	☑	☑	Lake chub	☑	☑	River carpsucker	☐	☐	Walleye
☑	☑	Brook stickleback	☑	☑	Largemouth bass	☐	☐	Rock bass	☑	☑	Western silvery minnow
☑	☑	Brown trout	☑	☑	Longnose dace	☑	☑	Sand shiner	☐	☐	White bass
☑	☑	Burbot	☑	☑	Longnose sucker	☑	☑	Sauger	☑	☑	White crappie
☐	☐	Catfish species	☐	☑	Minnow species	☑	☑	Shorthead redhorse	☑	☑	White sucker
☑	☑	Channel catfish	☐	☑	Mottled sculpin	☐	☐	Shortnose gar	☐	☐	Yellow bullhead
☑	☑	Common carp	☑	☑	Mountain sucker	☐	☐	Shovelnose sturgeon	☐	☑	Yellow perch
☐	☐	Creek chub	☑	☑	Mountain whitefish	☐	☐	Sicklefin chub			
☑	☑	Emerald shiner	☐	☐	Northern pike	☑	☑	Smallmouth bass			
☑	☑	Fathead minnow	☐	☐	Northern plains killifish	☐	☐	Smallmouth buffalo			

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	59.0	20.9	3.4%
Rip Rap Bottom	92.6	67.5	11.0%
Rip Rap Margin	19.4	11.8	1.9%
Bluff Pool	104.4	86.8	14.2%
Secondary Channel	10.3	16.5	2.7%
Secondary Channel (Seasonal)	132.4	90.6	14.8%
Channel Crossover	112.2	69.6	11.4%
Point Bar		15.4	2.5%
Side Bar		27.5	4.5%
Mid-channel Bar		27.3	4.5%
Island	81.5	81.5	13.3%
Dry Channel		96.2	15.7%

AVIAN

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

Bird Species Observed in Reach/Region

Species of Concern | Potential Species of Concern

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Yellowstone	**Upstream River Mile**	362.2
Classification	UB: Unconfined braided	**Downstream River Mile**	357.9
General Location	East Billings	**Length**	4.30 mi (6.92 km)
General Comments	Wide corridor d/s Billings; WAI Reach F		

Narrative Summary

Reach B3 is 4.3 miles long and located in east Billings. The reach is characterized by the loss of several miles of side channel, extensive Russian olive infestation, and substantial flow alterations due to human influences.

In total there are about 13,500 feet of bank armor in Reach B3, which covers almost 30 percent of the bankline. Most of the armor is rock riprap, although there are over 3,000 feet of flow deflectors mapped in the reach, as well as over a mile of floodplain dikes.

Prior to 1950, 11,000 feet of side channels had been blocked in the reach, and since that time another 14,000 feet have been similarly blocked by small dikes. These ~4 miles of blocked channel are about equivalent in length to that of the main river. That said, as of 2001 there were still about 35,000 feet of active side channel in Reach B3.

Solid waste dumps were mapped on old side channels on the east floodplain areas at RM 361.5 and RM 360.6. There is one major headgate on the left bank of the river that feeds a heavily armored canal at RM 359.9.

Flow alterations and channel blockages have promoted the encroachment of riparian vegetation into old channel areas. Since 1950, almost 200 acres of riparian vegetation colonized previously un-vegetated side channels. Floodplain turnover rates have gone down since 1976 by about 2 acres per year, indicating slower rates of erosion.

Since 1950, predominantly agricultural land uses in Reach B3 have been converted to a mix of agriculture and urban/exurban development. About 1,000 acres of urban/exurban development has taken place since 1950. About 470 acres of ground continues to be flood irrigated in this area of east Billings. Approximately 16 percent of the Channel Migration Zone has become restricted due to physical features, all of which are bank armor installations designed to protect urban/industrial and agricultural land uses.

About 50 acres of Russian olive have been mapped in Reach B3. There are also fairly extensive mapped wetlands, with about 230 acres of total wetland area mapped, 95 acres of which are emergent wet meadows and marsh areas.

Reach B3 was sampled as part of the fisheries study. A total of 29 fish species were sampled in the reach, and none of those species have been identified by the Montana Natural Heritage Program as a Species of Concern (SOC).

Reach B3 was sampled as part of the avian study. The average species richness in this reach was 7.5, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. One bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) was also found, the Plumbeous Vireo.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 23,900 cfs to 19,800 cfs, a drop of about 17 percent. The 2-year flood, which strongly influences overall channel form, has dropped from 44,500 cfs to 40,100 cfs, which is a reduction of 10 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,920 cfs to 2,010 cfs with human development, a reduction of 31 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,836 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B3 include:
•Riparian encroachment with flow alterations
Extensive armoring with CMZ encroachment

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B3 include:
•Side channel reactivation at RM 362.0, 360.5, 359.8 and RM 359.0
•Russian olive removal
•Solid waste dump removal RM 361.5 and RM 360.6
•Irrigation diversion structure management at RM 359.9.

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Billings

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	173.9	2.2

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	23,900	44,500	55,000	61,300	74,000	79,200	90,700	2,920	3,846
Regulated	19,800	40,100	50,900	57,500	71,000	76,600	89,100	2,010	2,227
% Change	-17.15%	-9.89%	-7.45%	-6.20%	-4.05%	-3.28%	-1.76%	-31.16%	-42.10%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	14-May-51	B/W	1:28,400	6214500	13200
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	23-Aug-96	B/W		6214500	4500
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	15-May-04	Color	1:15,840	6214500	5960
2005	NAIP	07/08/2005	color	1-meter pixels	6214500	11400
2009	NAIP	7/5/2009	Color	1-meter pixels	6214500	23800
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/24/2011	Color	1-meter pixels	6214500	22800
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	10,299	22.3%	10,047	21.7%	-252
	Flow Deflectors	731	1.6%	772	1.7%	41
	Concrete RipRap	592	1.3%	592	1.3%	0
	Between Flow Deflectors	2,338	5.1%	2,340	5.1%	1
	Feature Type Totals	**13,960**	**30.2%**	**13,751**	**29.7%**	**-209**
Floodplain Control						
	Transportation Encroachment	5,175	11.2%	5,175	11.2%	0
	Floodplain Dike/Levee	5,766	12.5%	5,766	12.5%	0
	Feature Type Totals	**10,941**	**23.7%**	**10,941**	**23.7%**	**0**
	Reach Totals	**24,901**	**53.8%**	**24,692**	**53.4%**	**-209**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	0	98	0	0	0	0	0	886
Flow Deflectors/Between FDs	1,351	0	0	0	0	0	1,535	1,492
Rock RipRap	0	0	0	0	0	0	3,123	0
Totals	**1,351**	**98**	**0**	**0**	**0**	**0**	**4,658**	**2,378**

Bankline/Floodplain Inventory: Time Series

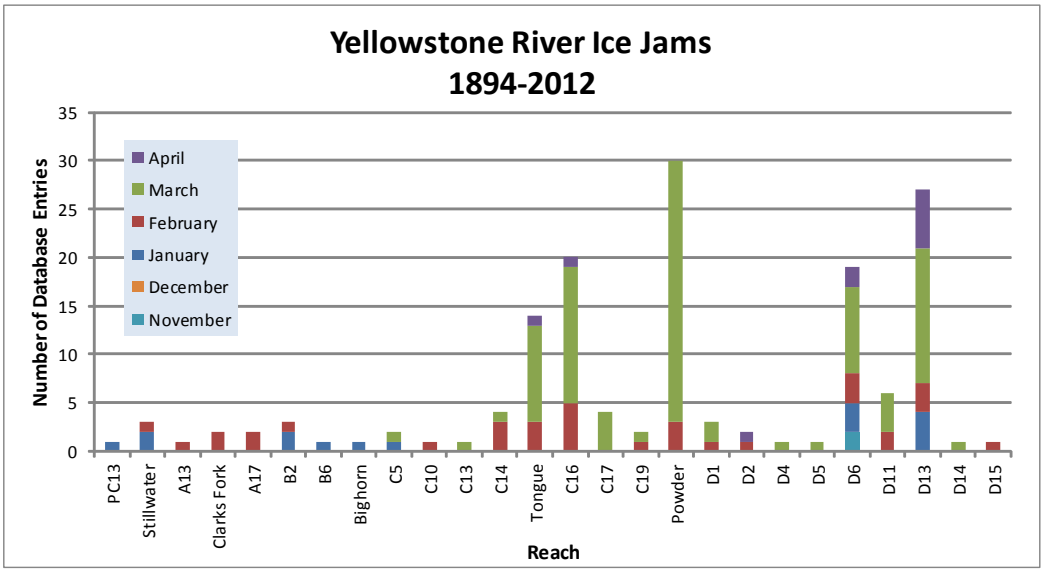
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	6,788	7,002	7,002	7,002	7,002	7,002
	Totals	**6,788**	**7,002**	**7,002**	**7,002**	**7,002**	**7,002**
Other							
	Floodplain Dike/Levee	7,446	7,446	7,446	7,446	7,446	7,446
	Totals	**7,446**	**7,446**	**7,446**	**7,446**	**7,446**	**7,446**
Other Off Channel							
	Floodplain Dike/Levee	0	2,866	6,494	6,494	6,494	6,494
	Floodplain Dike/Levee	155	7,025	9,010	9,010	9,010	9,010
	Totals	**155**	**9,891**	**15,504**	**15,504**	**15,504**	**15,504**
Stream Stabilization							

Rock RipRap	1,755	6,280	10,177	10,177	10,177	10,177
Flow Deflector	0	3,244	3,244	3,244	3,244	3,244
Concrete RipRap	0	0	592	592	592	592
Totals	**1,755**	**9,524**	**14,012**	**14,012**	**14,012**	**14,012**
Transportation Encroachment						
Railroad	5,149	5,149	5,149	5,149	5,149	5,149
Other	303	303	303	3,060	5,072	5,072
County Road	5,505	5,505	5,505	5,505	5,505	5,505
Totals	**10,957**	**10,957**	**10,957**	**13,714**	**15,726**	**15,726**

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	22,668	41,147	2.82	1950 to 1976:	-21.52%
1976	23,157	28,007	2.21	1976 to 1995:	11.22%
1995	22,999	33,516	2.46	1995 to 2001:	2.60%
2001	23,124	35,173	2.52	1950 to 2001:	-10.45%
Change 1950 - 2001	**456**	**-5,974**	**-0.29**		

Length of Side Channels Blocked

Pre-1950s (ft)	11,002
Post-1950s (ft)	13,693

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1640		1489	
Total Floodplain Area (Ac)	1640		1644	
Total Isolated (Ac)	**0**	**0.0%**	**155**	**14.1%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	76	0	0	**76**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
415	830	1,560	201	13%	64	64	100%

2011 Restricted Migration Area Summary

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

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Urban Industrial	105	6.4%
	Irrigated	129	7.9%
RipRap			
	Railroad	32	2.0%
	Totals	**266**	**16.3%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
60.5	0.0	0.0	216.9	5.5

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	50	67	71	51	1.3%	1.8%	1.9%	1.4%
	Totals	**50**	**67**	**71**	**51**	**1.3%**	**1.8%**	**1.9%**	**1.4%**
Agricultural Land									
	Non-Irrigated	2,297	1,703	1,387	1,297	60.5%	44.9%	36.5%	34.2%
	Irrigated	420	703	637	473	11.1%	18.5%	16.8%	12.4%
	Totals	**2,717**	**2,406**	**2,025**	**1,770**	**71.6%**	**63.4%**	**53.3%**	**46.6%**
Channel									
	Channel	870	906	837	853	22.9%	23.9%	22.1%	22.5%
	Totals	**870**	**906**	**837**	**853**	**22.9%**	**23.9%**	**22.1%**	**22.5%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	18	18	332	559	0.5%	0.5%	8.7%	14.7%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	3	14	39	57	0.1%	0.4%	1.0%	1.5%
	Totals	**21**	**32**	**371**	**616**	**0.6%**	**0.8%**	**9.8%**	**16.2%**
Transportation									
	Public Road	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	21	21	20	20	0.6%	0.6%	0.5%	0.5%
	Totals	**21**	**21**	**20**	**20**	**0.6%**	**0.6%**	**0.5%**	**0.5%**
Urban									
	Urban Other	0	0	40	27	0.0%	0.0%	1.1%	0.7%
	Urban Residential	0	96	171	182	0.0%	2.5%	4.5%	4.8%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	12	0	13	0.0%	0.3%	0.0%	0.4%
	Urban Industrial	116	256	261	263	3.1%	6.8%	6.9%	6.9%
	Totals	**116**	**365**	**473**	**485**	**3.1%**	**9.6%**	**12.5%**	**12.8%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	420	703	637	473	15.5%	29.2%	31.5%	26.7%	13.7%	2.3%	-4.8%	11.2%
	Totals	**420**	**703**	**637**	**473**	**15.5%**	**29.2%**	**31.5%**	**26.7%**	**13.7%**	**2.3%**	**-4.8%**	**11.2%**

Non-Irrigated

Multi-Use	1,401	1,252	1,137	1,023	51.5%	52.0%	56.2%	57.8%	0.5%	4.1%	1.7%	6.3%
Hay/Pasture	896	451	250	274	33.0%	18.8%	12.4%	15.5%	-14.2%	-6.4%	3.1%	-17.5%
Totals	**2,297**	**1,703**	**1,387**	**1,297**	**84.5%**	**70.8%**	**68.5%**	**73.3%**	**-13.7%**	**-2.3%**	**4.8%**	**-11.2%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	4.4	0.5	1.0	1.6	1.4	1.2	0.7	2.6	1.7
Max	74.7	195.9	173.6	147.6	90.2	152.0	91.3	42.9	89.2
Average	29.4	13.8	22.3	29.9	20.3	32.7	20.9	17.8	36.0
Sum	205.9	385.2	356.1	448.2	507.7	523.3	292.9	106.5	179.9

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	156.7
Channel to Riparian (acres)	214.1
Riparian Encroachment (acres)	**57.3**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	216.9
1950s Floodplain Mapped as 2011 Channel (Ac)	138.0
Total Recruitment (1950s to 2011)(Ac)	**355.0**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	95.8	94.9	40.5	0.0	**231.2**
Acres/Valley Mile	25.3	25.0	10.7	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	49.76	4.14%	45.71	7.40	11.57	5.58

FISHERIES SUMMARY

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

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

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

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

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
☐	☑	Bigmouth buffalo	☑	☑	Flathead chub	☐	☐	Northern redbelly dace	☑	☑	Stonecat
☐	☑	Black bullhead	☐	☐	Freshwater drum	☐	☐	Pallid sturgeon	☐	☐	Sturgeon chub
☑	☑	Black crappie	☑	☑	Goldeye	☑	☑	Pumpkinseed	☑	☑	Sucker species
☐	☐	Blue sucker	☑	☑	Green sunfish	☑	☑	Rainbow trout	☐	☑	Sunfish species
☑	☑	Bluegill	☑	☑	Lake chub	☐	☑	River carpsucker	☐	☐	Walleye
☑	☑	Brook stickleback	☑	☑	Largemouth bass	☐	☐	Rock bass	☑	☑	Western silvery minnow
☑	☑	Brown trout	☑	☑	Longnose dace	☑	☑	Sand shiner	☐	☐	White bass
☐	☑	Burbot	☑	☑	Longnose sucker	☐	☑	Sauger	☑	☑	White crappie
☐	☐	Catfish species	☐	☑	Minnow species	☑	☑	Shorthead redhorse	☑	☑	White sucker
☑	☑	Channel catfish	☑	☑	Mottled sculpin	☐	☐	Shortnose gar	☐	☐	Yellow bullhead
☑	☑	Common carp	☑	☑	Mountain sucker	☐	☐	Shovelnose sturgeon	☑	☑	Yellow perch
☐	☐	Creek chub	☑	☑	Mountain whitefish	☐	☐	Sicklefin chub			
☑	☑	Emerald shiner	☐	☐	Northern pike	☑	☑	Smallmouth bass			
☑	☑	Fathead minnow	☐	☐	Northern plains killifish	☐	☐	Smallmouth buffalo			

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	48.5	45.2	5.4%
Rip Rap Bottom	95.6	52.8	6.3%
Rip Rap Margin	28.3	13.1	1.6%
Secondary Channel	40.8	15.5	1.8%
Secondary Channel (Seasonal)	211.2	126.3	15.1%
Channel Crossover	116.1	47.6	5.7%
Point Bar		27.0	3.2%
Side Bar		44.3	5.3%
Mid-channel Bar		8.4	1.0%
Island	296.7	296.7	35.4%
Dry Channel		160.1	19.1%

AVIAN

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

Bird Species Observed in Reach/Region

Species of Concern | Potential Species of Concern

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

Yellowstone River Reach Narratives — Reach B4

County	Yellowstone	**Upstream River Mile**	357.9
Classification	PCS: Partially confined straight	**Downstream River Mile**	354
General Location	Upstream of Huntley	**Length**	3.90 mi (6.28 km)
General Comments	Channel closely follows right valey wall; extensive bank armor		

Narrative Summary

Reach B4 is 3.9 miles long and located upstream of Huntley. It is classified as a Partially Confined Straight (PCS) reach type because within this area the river flows straight along the south valley wall with minimal meandering. The reach is characterized by the most extensive bank armoring of any reach on the river.

In total there are about 29,000 feet of bank protection in Reach B4, such that 74 percent of the bankline is armored. Most of the armor is rock riprap, although there are over 8,000 feet of concrete riprap mapped in the reach, as well as over 9,000 feet of floodplain dikes. Between 2001 and 2011, 500 feet of concrete riprap and 1,050 feet of flow deflectors were eroded out in the reach. The failed flow deflectors and concrete riprap have been largely replaced by rock riprap, although at the upstream end of the reach at RM 357.8, about 300 feet of flanked flow deflectors are in the river about 75 feet off of the left (north) bank.

The predominant land use in the reach is agriculture, with about 1,200 acres of land in flood irrigation in 2011. A total of 204 acres of developed land uses have encroached into the Channel Migration Zone (CMZ), including 193 acres of flood irrigation and 11 acres of transportation corridor. In order to protect these land uses, bank armor installations have isolated about one half of the river's CMZ.

Huntley Diversion Dam is located at RM 355.8. The structure diverts flow into the Huntley Main Canal, which follows the southern margin of the Yellowstone River floodplain. The diversion capacity of Huntley Dam is 600 cfs, and the project has the capacity to provide irrigation water to 30,000 acres of farm land. The crest length of the structure is 325 feet, and its structural height is 10.5 feet (http://www.usbr.gov/dataweb/dams/yellowstone_river_diversion.htm). The Huntley diversion structure was originally constructed as a temporary earthfill dam in 1931. In 1934, the temporary structure was modified to a concrete weir. In 1959, the dam underwent considerable rehabilitation due to undermining caused by settling and cracking of the concrete structure. As part of repairs required after recent flooding on the river, a fish passage channel was constructed around the north end of the dam. The structure is located at a point of split flow on the river, and blocks only the main channel. However, 2001 color infrared air photos of the site show that at low flows, the unblocked secondary channels are essentially dry and therefore incapable of passing fish.

Land has been developed in commonly flooded areas. About 280 acres of flood irrigated land is within the 5-year floodplain area.

There are corrals that are part of an animal handling facility adjacent to the north bank of the river at RM 355.

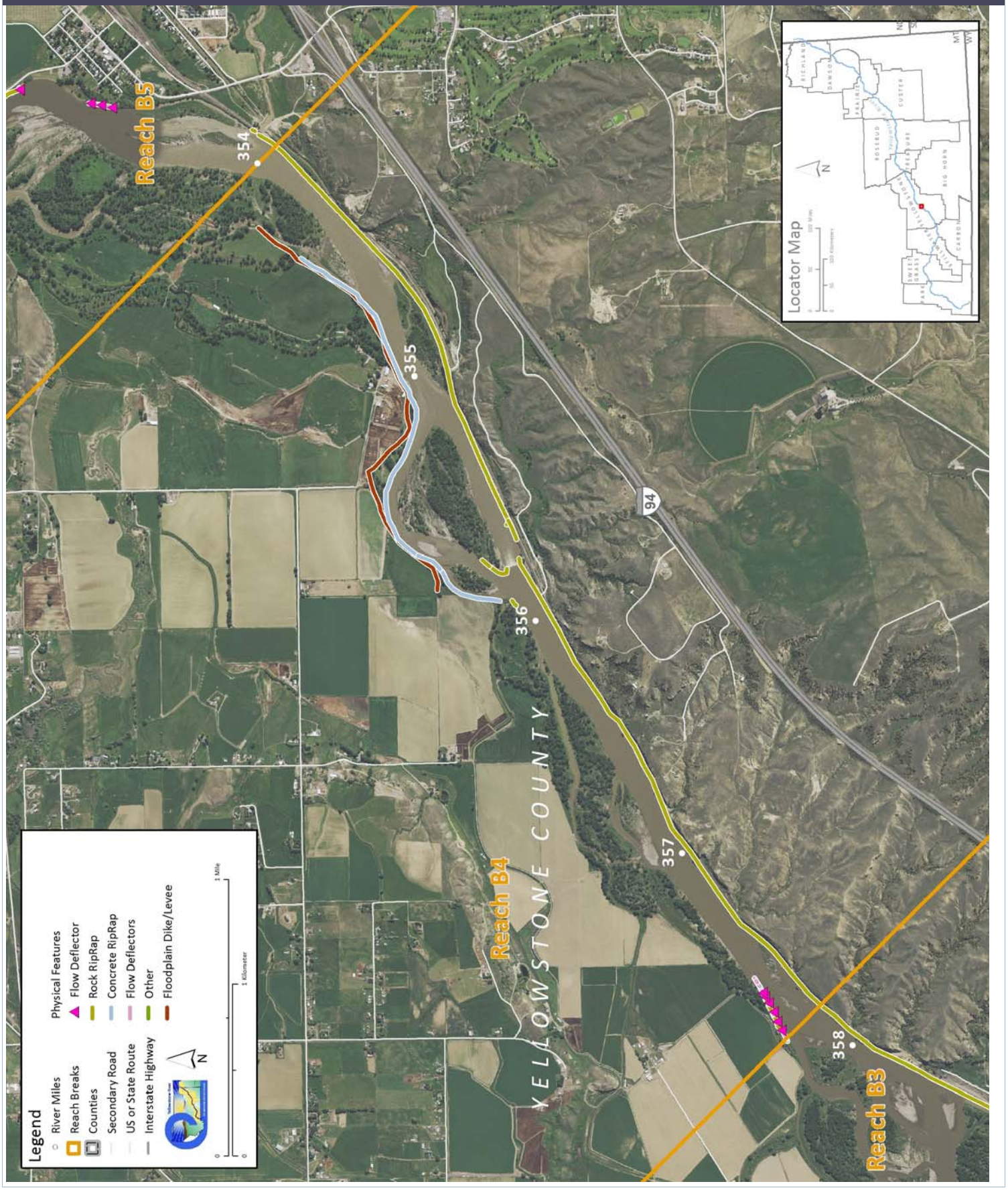
About 2.3 acres of Russian olive have been mapped in Reach B4.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 24,000 cfs to 19,900 cfs, a drop of about 17 percent. The 2-year flood, which strongly influences overall channel form, has dropped from 44,700 cfs to 40,300 cfs, which is a reduction of 10 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,940 cfs to 2,010 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B4 include:
•Flanking of flow deflectors
•Repair of damaged flow deflectors with riprap

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B4 include:
•Flanked flow deflector removal at RM 357.8
•Nutrient management at corrals associated with animal handling facility at RM 355.
•Fish passage at Huntley Diversion Dam
•Watercraft passage at Huntley Diversion Dam
•Irrigation Diversion structure management at Huntley Diversion Dam

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	170.0	6.5

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	24,000	44,700	55,100	61,400	74,300	79,400	91,000	2,940	3,846
Regulated	19,900	40,300	51,000	57,500	71,300	76,800	89,400	2,010	2,227
% Change	-17.08%	-9.84%	-7.44%	-6.35%	-4.04%	-3.27%	-1.76%	-31.63%	-42.10%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	14-May-51	B/W	1:28,400	6214500	13200
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	23-Aug-96	B/W		6214500	4500
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	15-May-04	Color	1:15,840	6214500	5960
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2005	NAIP	07/08/2005	color	1-meter pixels	6214500	11400
2009	NAIP	7/5/2009	Color	1-meter pixels	6214500	23800
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/24/2011	Color	1-meter pixels	6214500	22800
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	19,525	49.1%	20,730	52.1%	1,205
	Flow Deflectors	338	0.8%	258	0.6%	-80
	Concrete RipRap	8,833	22.2%	8,332	20.9%	-502
	Between Flow Deflectors	976	2.5%	0	0.0%	-976
	Feature Type Totals	**29,672**	**74.6%**	**29,319**	**73.7%**	**-353**
Floodplain Control						
	Transportation Encroachment	4,465	11.2%	4,465	11.2%	0
	Floodplain Dike/Levee	8,976	22.6%	8,976	22.6%	0
	Feature Type Totals	**13,441**	**33.8%**	**13,441**	**33.8%**	**0**
	Reach Totals	**43,113**	**108.3%**	**42,760**	**107.5%**	**-353**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	5,550	0	3,280	0	0	0	0	0
Rock RipRap	3,004	0	462	0	0	23,705	0	0
Totals	**8,554**	**0**	**3,742**	**0**	**0**	**23,705**	**0**	**0**

Bankline/Floodplain Inventory: Time Series

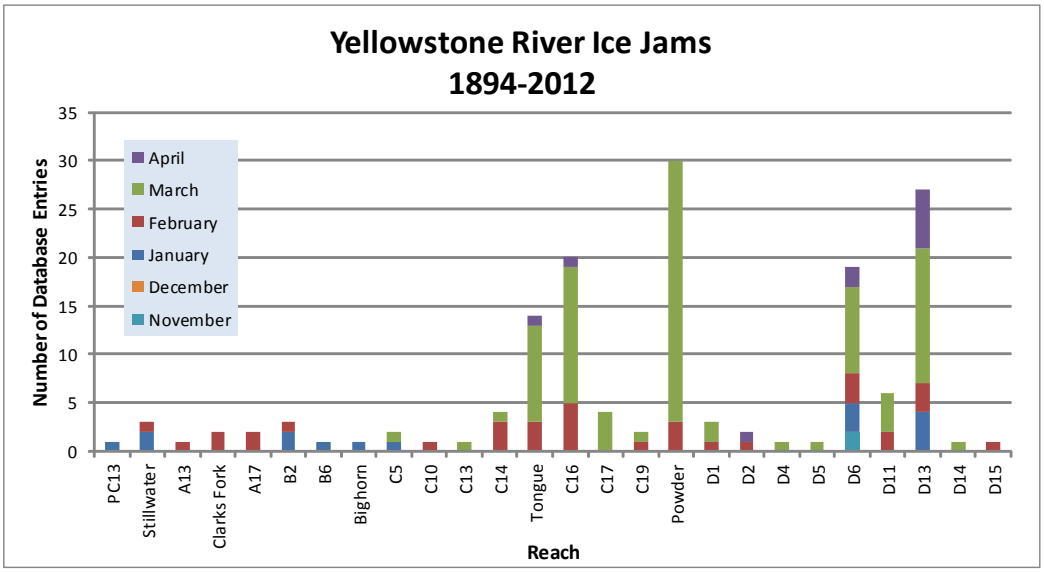
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	In Channel Diversion	237	474	237	237	237	237
	Floodplain Dike/Levee	13,375	13,375	13,375	13,375	13,375	13,375
	Totals	**13,612**	**13,849**	**13,612**	**13,612**	**13,612**	**13,612**
Other Off Channel							
	Floodplain Dike/Levee	0	4,705	4,705	4,705	4,705	4,705
	Floodplain Dike/Levee	0	4,300	4,300	4,300	4,300	4,300
	Totals	**0**	**9,005**	**9,005**	**9,005**	**9,005**	**9,005**
Stream Stabilization							
	Rock RipRap	18,166	18,166	18,166	18,406	18,406	18,406
	Flow Deflector	0	3,241	3,241	3,241	3,241	3,241
	Concrete RipRap	0	6,452	6,452	6,960	6,960	6,960

Totals	**18,166**	**27,859**	**27,859**	**28,607**	**28,607**	**28,607**
Transportation Encroachment						
Railroad	13,543	13,543	13,543	13,543	13,543	13,543
Other	619	619	619	619	619	619
Totals	**14,162**	**14,162**	**14,162**	**14,162**	**14,162**	**14,162**

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	19,950	9,303	1.47	1950 to 1976:	-2.55%
1976	20,116	8,627	1.43	1976 to 1995:	-3.42%
1995	20,165	7,663	1.38	1995 to 2001:	14.31%
2001	19,897	11,490	1.58	1950 to 2001:	7.58%
Change 1950 - 2001	**-53**	**2,188**	**0.11**		

Length of Side Channels Blocked

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

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	29	2.2%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1262		1159	
Total Floodplain Area (Ac)	1291		1290	
Total Isolated (Ac)	**29**	**2.2%**	**132**	**14.1%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	279	0	0	**279**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
332	663	831	236	28%	266	249	93%

2011 Restricted Migration Area Summary

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

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Irrigated	26	2.3%
RipRap			
	Railroad	63	5.7%
	Irrigated	396	35.8%
	Totals	**484**	**43.8%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
193.1	0.0	0.0	0.0	10.8

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	6	6	6	6	0.2%	0.2%	0.2%	0.2%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	70	128	157	162	2.1%	3.9%	4.8%	5.0%
	Totals	**76**	**134**	**163**	**168**	**2.3%**	**4.1%**	**5.0%**	**5.1%**
Agricultural Land									
	Non-Irrigated	2,048	1,520	1,338	1,391	62.8%	46.6%	41.0%	42.7%
	Irrigated	728	1,167	1,261	1,161	22.3%	35.8%	38.7%	35.6%
	Totals	**2,775**	**2,686**	**2,599**	**2,552**	**85.1%**	**82.4%**	**79.7%**	**78.3%**
Channel									
	Channel	388	380	423	440	11.9%	11.7%	13.0%	13.5%
	Totals	**388**	**380**	**423**	**440**	**11.9%**	**11.7%**	**13.0%**	**13.5%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	5	0.0%	0.0%	0.0%	0.1%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	17	36	0.0%	0.0%	0.5%	1.1%
	Totals	**0**	**0**	**17**	**41**	**0.0%**	**0.0%**	**0.5%**	**1.3%**
Transportation									
	Public Road	8	8	8	8	0.2%	0.2%	0.2%	0.2%
	Interstate	0	30	30	30	0.0%	0.9%	0.9%	0.9%
	Railroad	14	22	22	22	0.4%	0.7%	0.7%	0.7%
	Totals	**22**	**60**	**59**	**59**	**0.7%**	**1.8%**	**1.8%**	**1.8%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	728	1,167	1,261	1,161	26.2%	43.4%	48.5%	45.5%	17.2%	5.1%	-3.0%	19.3%
	Totals	**728**	**1,167**	**1,261**	**1,161**	**26.2%**	**43.4%**	**48.5%**	**45.5%**	**17.2%**	**5.1%**	**-3.0%**	**19.3%**

Non-Irrigated

Multi-Use	1,394	1,284	1,333	1,271	50.2%	47.8%	51.3%	49.8%	-2.4%	3.5%	-1.5%	-0.4%
Hay/Pasture	654	235	4	120	23.6%	8.8%	0.2%	4.7%	-14.8%	-8.6%	4.5%	-18.9%
Totals	**2,048**	**1,520**	**1,338**	**1,391**	**73.8%**	**56.6%**	**51.5%**	**54.5%**	**-17.2%**	**-5.1%**	**3.0%**	**-19.3%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	7.6	1.2	1.8	2.5	2.4	1.2	4.0	2.9	1.9
Max	29.2	7.6	34.1	111.8	129.6	136.5	26.2	34.4	40.6
Average	17.1	4.9	14.2	35.4	40.3	23.2	17.8	17.7	13.1
Sum	102.5	24.6	85.3	283.4	282.0	208.4	53.3	53.1	117.6

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	82.4
Channel to Riparian (acres)	68.2
Riparian Encroachment (acres)	**-14.2**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	68.0
1950s Floodplain Mapped as 2011 Channel (Ac)	16.4
Total Recruitment (1950s to 2011)(Ac)	**84.4**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	17.0	34.3	8.1	0.0	**59.5**
Acres/Valley Mile	4.6	9.2	2.2	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	2.29	1.08%	16.12	0.49	0.70	0.08

FISHERIES SUMMARY

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

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

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

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

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
☐	☑	Bigmouth buffalo	☑	☑	Flathead chub	☐	☐	Northern redbelly dace	☑	☑	Stonecat
☑	☑	Black bullhead	☐	☐	Freshwater drum	☐	☐	Pallid sturgeon	☐	☐	Sturgeon chub
☐	☑	Black crappie	☑	☑	Goldeye	☐	☑	Pumpkinseed	☑	☑	Sucker species
☐	☐	Blue sucker	☑	☑	Green sunfish	☑	☑	Rainbow trout	☐	☑	Sunfish species
☑	☑	Bluegill	☐	☑	Lake chub	☑	☑	River carpsucker	☐	☐	Walleye
☑	☑	Brook stickleback	☑	☑	Largemouth bass	☐	☐	Rock bass	☑	☑	Western silvery minnow
☑	☑	Brown trout	☑	☑	Longnose dace	☑	☑	Sand shiner	☐	☐	White bass
☐	☑	Burbot	☑	☑	Longnose sucker	☐	☑	Sauger	☐	☑	White crappie
☐	☐	Catfish species	☐	☑	Minnow species	☑	☑	Shorthead redhorse	☑	☑	White sucker
☑	☑	Channel catfish	☐	☑	Mottled sculpin	☐	☐	Shortnose gar	☐	☐	Yellow bullhead
☑	☑	Common carp	☑	☑	Mountain sucker	☐	☐	Shovelnose sturgeon	☑	☑	Yellow perch
☐	☐	Creek chub	☑	☑	Mountain whitefish	☐	☐	Sicklefin chub			
☑	☑	Emerald shiner	☐	☐	Northern pike	☑	☑	Smallmouth bass			
☑	☑	Fathead minnow	☐	☐	Northern plains killifish	☐	☐	Smallmouth buffalo			

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Rip Rap Bottom	48.1	23.2	5.5%
Rip Rap Margin	96.3	56.3	13.3%
Secondary Channel	0.7	0.6	0.1%
Secondary Channel (Seasonal)	78.7	53.2	12.6%
Channel Crossover	58.6	28.9	6.8%
Point Bar		11.4	2.7%
Side Bar		23.2	5.5%
Mid-channel Bar		18.0	4.2%
Island	80.9	80.9	19.1%
Dry Channel		77.8	18.4%
Dam Influenced	59.4	49.2	11.6%

AVIAN

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

Yellowstone River Reach Narratives — Reach B5

County	Yellowstone	**Upstream River Mile**	354
Classification	UA: Unconfined anabranching	**Downstream River Mile**	346.7
General Location	Huntley: includes Spraklin Island	**Length**	7.30 mi (11.75 km)
General Comments	Just downstream of Huntley, Reach B5 provides a good example of floodplain isolation by structures, which is potentially exacerbated by hydrologic alterations.		

Narrative Summary

Reach B5 is 7.4 miles long and is located near Huntley and Spraklin Island. The reach is an Unconfined Anabranching (UA) reach type, which indicates little influence by the valley wall coupled with relatively extensive forested islands and side channels. These reach types tend to be the most dynamic within the river corridor. Reach B5 flows northward though a wide valley section where the relatively erodible Bearpaw shale has retreated over geologic time, leaving an unusually broad river corridor. In Reach B5 the river crosses the valley from south to north, further contributing to the lack of confinement and allowance for channel migration.

About 12 percent of the bankline in Reach B5 is armored. In 2011, there was about a mile of concrete riprap, a half mile of rock riprap, and 1,500 feet of flow deflectors in the reach. Over the decade prior to that, however, 1,200 feet of concrete riprap and 1,150 feet of flow deflectors had eroded out, and 2,000 feet of rock riprap built, indicating a tendency for concrete and flow deflectors to fail coupled by an overall shift towards rock riprap bank protection between 2001 and 2011.

One of the most spectacular examples of barb failures on the Yellowstone River is in Reach B5, where about 1,300 feet of barbs on the left bank just downstream of the Huntley Bridge were flanked between 2001 and 2005. The river then migrated about 200 feet behind the barbs and the bank has since been armored with rock riprap. The flanked barbs remain visible in the middle of the river in 2011 imagery. Another barb was flanked on the left bank at RM 350, and is prominently exposed 65 feet off of the bank. In the lowermost end of the reach at RM 347, about 900 feet of concrete armor was flanked on the right bank, and the river is now up to 200 feet behind the armor, migrating rapidly to the east. This area has seen over 800 feet of river migration since 1950.

Prior to 1950, about 11,400 feet of side channels were blocked in the reach by small dikes. These channels are on both sides of the river just downstream of the Huntley Bridge at RM 352.5. Further downstream at RM 348 there are numerous older swales south of the river that are also blocked.

Land uses in the reach are primarily agricultural, with about 1,300 acres of flood irrigated land mapped as of 2011. There are also almost 600 acres of urban/exurban development. The Channel Migration Zone (CMZ) has been developed for multiple land uses; as of 2011, there were 389 acres of flood irrigation, 24 acres of urban/exurban land, and 10 acres of transportation infrastructure within the CMZ. About 14 percent of the total CMZ footprint has become restricted by bank armor and road prisms.

Trash dumps have been mapped on the left stream bank at RM 351.2, and up on the north bluff at RM 347.1. One large animal handling facility was mapped about 800 feet south of the river at RM 347.8.

About 55 acres of Russian olive have been mapped in Reach B5. The reach also hosts over 200 acres of mapped wetland areas, about 170 acres of which are emergent marshes and wet meadows.

Riparian recruitment in the reach has exceeded 500 acres since 1950; about half of that recruitment occurred in areas that were 1950s channel and the other half in areas that were eroded between 1950 and 2001.

Reach B5 was sampled as part of the avian study. The average species richness in this reach was 8.4, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. Two bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were also found, the Plumbeous Vireo and the Ovenbird.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 25,600 cfs to 21,200 cfs, a drop of about 17 percent. The 2-year flood, which strongly influences overall channel form, has dropped from 47,400 cfs to 42,600 cfs, which is a reduction of 10 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,000 cfs to 2,050 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

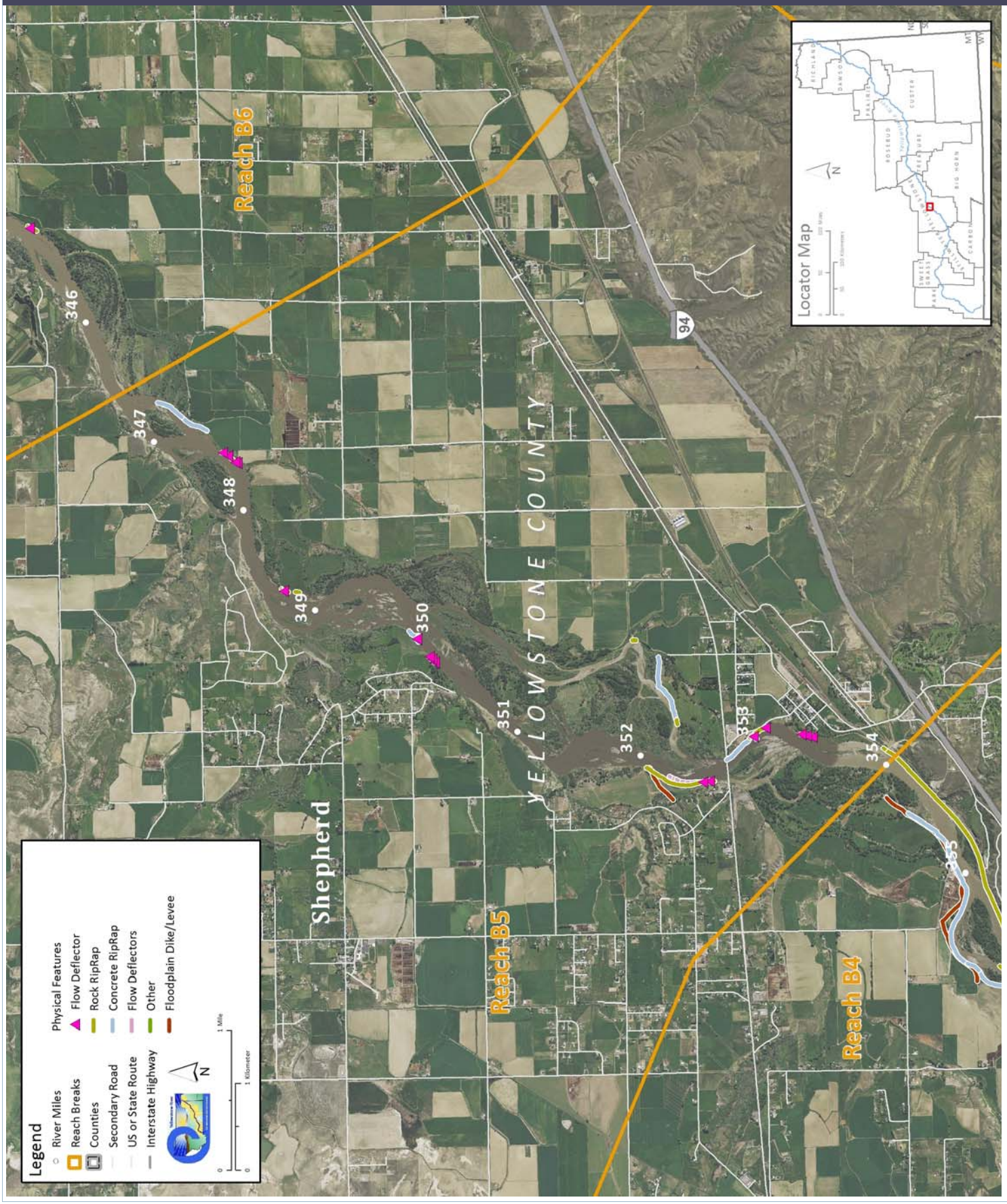
Because of the flow alterations, about 22 percent of the 5-year floodplain has become isolated in Reach B5.

CEA-Related observations in Reach B5 include:
•Flanking of flow deflectors and concrete riprap
•Blockage of over two miles of side channel pre-1950

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B5 include:
•Side channel restoration at RM 352.5
•Flanked flow deflector removal at RM 352.5 and 350.0
•CMZ management due to development within CMZ footprint
•Russian olive removal

•Nutrient management at animal handling facility at RM 347.8.
•Solid waste removal at RM 351.2L and 347.1L

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	162.7	10.4

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	25,600	47,400	58,400	65,100	78,600	84,000	96,100	3,000	3,846
Regulated	21,200	42,600	54,000	61,000	75,400	81,200	94,400	2,050	2,227
% Change	-17.19%	-10.13%	-7.53%	-6.30%	-4.07%	-3.33%	-1.77%	-31.67%	-42.10%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	14-May-51	B/W	1:28,400	6214500	13200
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	8/23/96 - 8/10/96	B/W		6214500	4500
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	15-May-04	Color	1:15,840	6214500	5960
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2009	NAIP	7/5/2009	Color	1-meter pixels	6214500	23800
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/24/2011	Color	1-meter pixels	6214500	22800
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	552	0.7%	2,399	3.1%	1,847
	Flow Deflectors	587	0.7%	736	0.9%	150
	Concrete RipRap	6,579	8.4%	5,361	6.8%	-1,218
	Between Flow Deflectors	2,116	2.7%	813	1.0%	-1,303
	Feature Type Totals	**9,833**	**12.5%**	**9,310**	**11.9%**	**-523**
Floodplain Control						
	Transportation Encroachment	2,694	3.4%	2,694	3.4%	0
	Floodplain Dike/Levee	2,055	2.6%	1,936	2.5%	-119
	Feature Type Totals	**4,749**	**6.1%**	**4,630**	**5.9%**	**-119**
	Reach Totals	**14,582**	**18.6%**	**13,940**	**17.8%**	**-643**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	3,172	1,082	1,099	1,223	0	0	0	0
Flow Deflectors/Between FDs	0	1,617	610	0	0	0	0	476
Rock RipRap	171	0	0	0	0	0	0	0
Totals	**3,342**	**2,699**	**1,709**	**1,223**	**0**	**0**	**0**	**476**

Bankline/Floodplain Inventory: Time Series

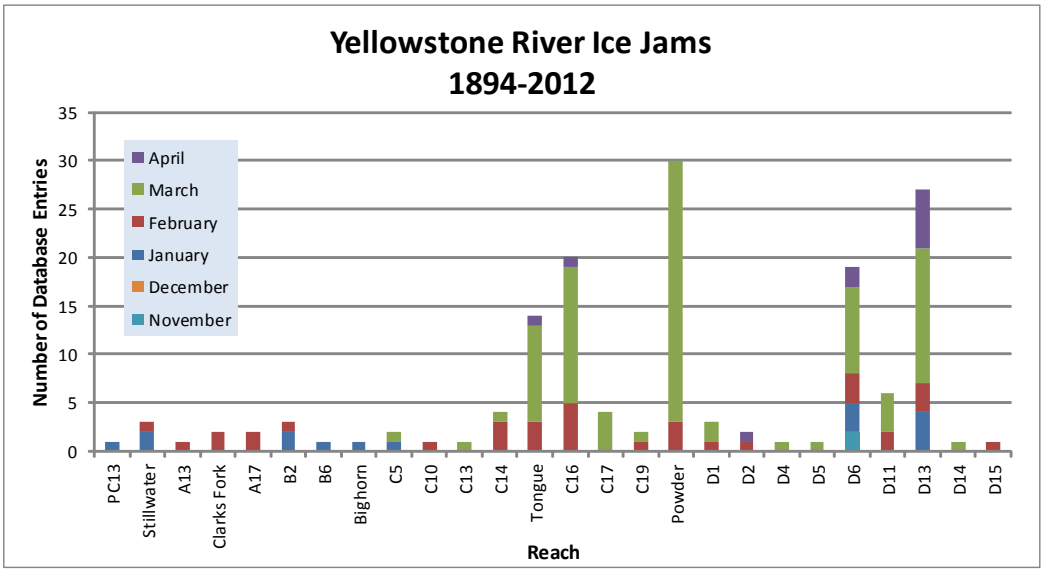
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	1,736	1,736	1,736	1,736	1,736	1,736
	Totals	**1,736**	**1,736**	**1,736**	**1,736**	**1,736**	**1,736**
Other Off Channel							
	Floodplain Dike/Levee	0	2,444	2,444	2,444	2,444	2,444
	Floodplain Dike/Levee	449	449	449	449	449	449
	Totals	**449**	**2,893**	**2,893**	**2,893**	**2,893**	**2,893**
Stream Stabilization							
	Rock RipRap	2,422	2,594	2,594	2,594	2,594	2,594
	Flow Deflector	0	645	645	2,736	1,391	1,391
	Concrete RipRap	2,429	5,218	8,316	9,344	9,344	9,344

Totals	**4,851**	**8,457**	**11,555**	**14,674**	**13,328**	**13,328**
Transportation Encroachment						
Railroad	1,238	1,238	1,238	1,238	1,238	1,238
Other	114	114	209	209	318	318
County Road	2,565	2,565	2,565	2,565	2,565	2,565
Bridge Approach	2,496	2,496	2,496	2,496	2,496	2,496
Totals	**6,412**	**6,412**	**6,507**	**6,507**	**6,617**	**6,617**

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	39,051	58,430	2.50	1950 to 1976:	-2.39%
1976	39,578	56,859	2.44	1976 to 1995:	-3.13%
1995	39,826	54,179	2.36	1995 to 2001:	13.93%
2001	39,214	66,239	2.69	1950 to 2001:	7.73%
Change 1950 - 2001	**163**	**7,809**	**0.19**		

Length of Side Channels Blocked

Pre-1950s (ft)	11,393
Post-1950s (ft)	0

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	12	0.5%		
Total Not Isolated (Ac)	2320		1956	
Total Floodplain Area (Ac)	2332		2209	
Total Isolated (Ac)	**12**	**0.5%**	**253**	**21.5%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	106	0	0	**106**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
430	860	2,704	322	12%	91	55	60%

2011 Restricted Migration Area Summary

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	66	2.3%
	Public Road	69	2.4%
RipRap/Flow Deflectors			
	Irrigated	109	3.9%
RipRap			
	Public Road	126	4.5%
	Irrigated	27	0.9%
	Totals	**396**	**14.0%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
305.1	0.0	0.0	50.4	12.5

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	12	12	12	12	0.2%	0.2%	0.2%	0.2%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	81	99	130	147	1.5%	1.8%	2.4%	2.7%
	Totals	**93**	**111**	**142**	**159**	**1.7%**	**2.0%**	**2.6%**	**2.9%**
Agricultural Land									
	Non-Irrigated	2,810	2,108	1,514	1,770	51.5%	38.6%	27.8%	32.5%
	Irrigated	921	1,476	1,644	1,271	16.9%	27.1%	30.2%	23.3%
	Totals	**3,731**	**3,584**	**3,158**	**3,041**	**68.4%**	**65.7%**	**57.9%**	**55.8%**
Channel									
	Channel	1,522	1,428	1,601	1,637	27.9%	26.2%	29.4%	30.0%
	Totals	**1,522**	**1,428**	**1,601**	**1,637**	**27.9%**	**26.2%**	**29.4%**	**30.0%**
ExUrban									
	ExUrban Other	0	7	0	0	0.0%	0.1%	0.0%	0.0%
	ExUrban Undeveloped	20	40	4	4	0.4%	0.7%	0.1%	0.1%
	ExUrban Industrial	0	0	12	12	0.0%	0.0%	0.2%	0.2%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	43	234	488	552	0.8%	4.3%	8.9%	10.1%
	Totals	**63**	**281**	**503**	**567**	**1.2%**	**5.1%**	**9.2%**	**10.4%**
Transportation									
	Public Road	40	39	39	39	0.7%	0.7%	0.7%	0.7%
	Interstate	0	2	2	2	0.0%	0.0%	0.0%	0.0%
	Railroad	5	7	7	7	0.1%	0.1%	0.1%	0.1%
	Totals	**45**	**49**	**49**	**49**	**0.8%**	**0.9%**	**0.9%**	**0.9%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	1	1	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**1**	**1**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	921	1,476	1,644	1,271	24.7%	41.2%	52.1%	41.8%	16.5%	10.9%	-10.3%	17.1%
	Totals	**921**	**1,476**	**1,644**	**1,271**	**24.7%**	**41.2%**	**52.1%**	**41.8%**	**16.5%**	**10.9%**	**-10.3%**	**17.1%**

Non-Irrigated

Multi-Use	1,525	1,448	1,192	1,368	40.9%	40.4%	37.7%	45.0%	-0.5%	-2.7%	7.2%	4.1%
Hay/Pasture	1,286	660	321	402	34.5%	18.4%	10.2%	13.2%	-16.0%	-8.2%	3.0%	-21.2%
Totals	**2,810**	**2,108**	**1,514**	**1,770**	**75.3%**	**58.8%**	**47.9%**	**58.2%**	**-16.5%**	**-10.9%**	**10.3%**	**-17.1%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.1	0.4	0.1	0.0	0.8	0.6	2.7	1.7	0.2
Max	28.5	67.0	24.9	153.1	171.3	127.2	59.8	31.3	71.5
Average	12.2	10.2	7.3	33.5	31.4	25.1	23.2	17.0	19.1
Sum	268.2	286.5	174.3	636.7	784.5	678.9	370.4	220.5	420.8

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	339.8
Channel to Riparian (acres)	283.6
Riparian Encroachment (acres)	**-56.2**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	285.2
1950s Floodplain Mapped as 2011 Channel (Ac)	239.5
Total Recruitment (1950s to 2011)(Ac)	**524.7**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	17.7	169.8	52.3	0.0	**239.8**
Acres/Valley Mile	2.8	27.1	8.3	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	54.53	3.21%	53.49	5.19	15.73	8.16

FISHERIES SUMMARY

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

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

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

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

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	140.7	68.5	4.2%
Rip Rap Bottom	87.3	46.8	2.9%
Bluff Pool	84.7	60.5	3.7%
Secondary Channel	299.1	117.7	7.2%
Secondary Channel (Seasonal)	252.4	162.3	9.9%
Channel Crossover	150.3	72.0	4.4%
Point Bar		93.1	5.7%
Side Bar		97.2	6.0%
Mid-channel Bar		56.8	3.5%
Island	617.4	617.4	37.8%
Dry Channel		239.5	14.7%

AVIAN

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

Bird Species Observed in Reach/Region

Species of Concern | Potential Species of Concern

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

Yellowstone River Reach Narratives — Reach B6

County	Yellowstone	**Upstream River Mile**	346.7
Classification	PCB: Partially confined braided	**Downstream River Mile**	340.6
General Location	Ballantine	**Length**	6.10 mi (9.82 km)
General Comments	Channel closely follows left valley wall		

Narrative Summary

Reach B6 is 6.1 miles long and is located Ballantine. The reach is a Partially Confined Braided (PCB) reach type, which indicates some valley wall influence coupled with relatively extensive unvegetated bars and low flow islands. Within Reach B6, the river flows closely along the north valley wall. The Gritty Stone fishing access site is located in the downstream end of the reach.

About 6.3 percent of the bankline in Reach B6 is armored, and the majority of that armor (2,300 feet) is concrete riprap. Since 2001, riprap has expanded by about 430 feet. Reach B6 also hosts almost 1,500 feet of car body riprap, which is fairly unusual in terms of extent on the Yellowstone River. The car bodies were put in place between 1950 and 1995, and their mapped location is at RM 341.7R, although they are difficult to see on the imagery.

Prior to 1950, a side channel that was about 1,350 feet long was blocked by a small dike at RM 343. Even though this side channel was blocked, there has been a net gain of over three miles of side channel since 1950.

Land uses in the reach are primarily agricultural, with about 1,862 acres of flood irrigated land mapped as of 2011. The Channel Migration Zone (CMZ) has been developed for primarily flood irrigation; as of 2011, there were 237 acres of flood irrigated land in the CMZ, and about 9 percent of the total CMZ footprint has become restricted by bank armor and road prisms. The modern 5-year floodplain contains over 200 acres of flood-irrigated ground.

There is one mapped animal handling facility in the reach at RM 345.5R. It is within 800 feet of the active river bank.

The 100-year floodplain has also been restricted; about 210 acres or 11.4 percent of the historic 100-year floodplain area has become isolated from the river by agricultural infrastructure.

Since 1950, there has been almost 250 acres of riparian recruitment in the reach, and most of that was in the 1950s channels that were abandoned.

One ice jam has been recorded in Reach B6. On January 3, 1997, an ice jam occurred at RM 345 that caused severe flooding and resulted in evacuations.

There are 49 acres of mapped Russian olive in the reach, and the mapping indicates that it has expanded on islands and in side channels. Riparian recruitment in the reach has exceeded 500 acres since 1950; about half of that recruitment occurred in areas that were 1950s channel and the other half in areas that were eroded between 1950 and 2001.

Reach B6 was sampled as part of the avian study. The average species richness in this reach was 8.25, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8.

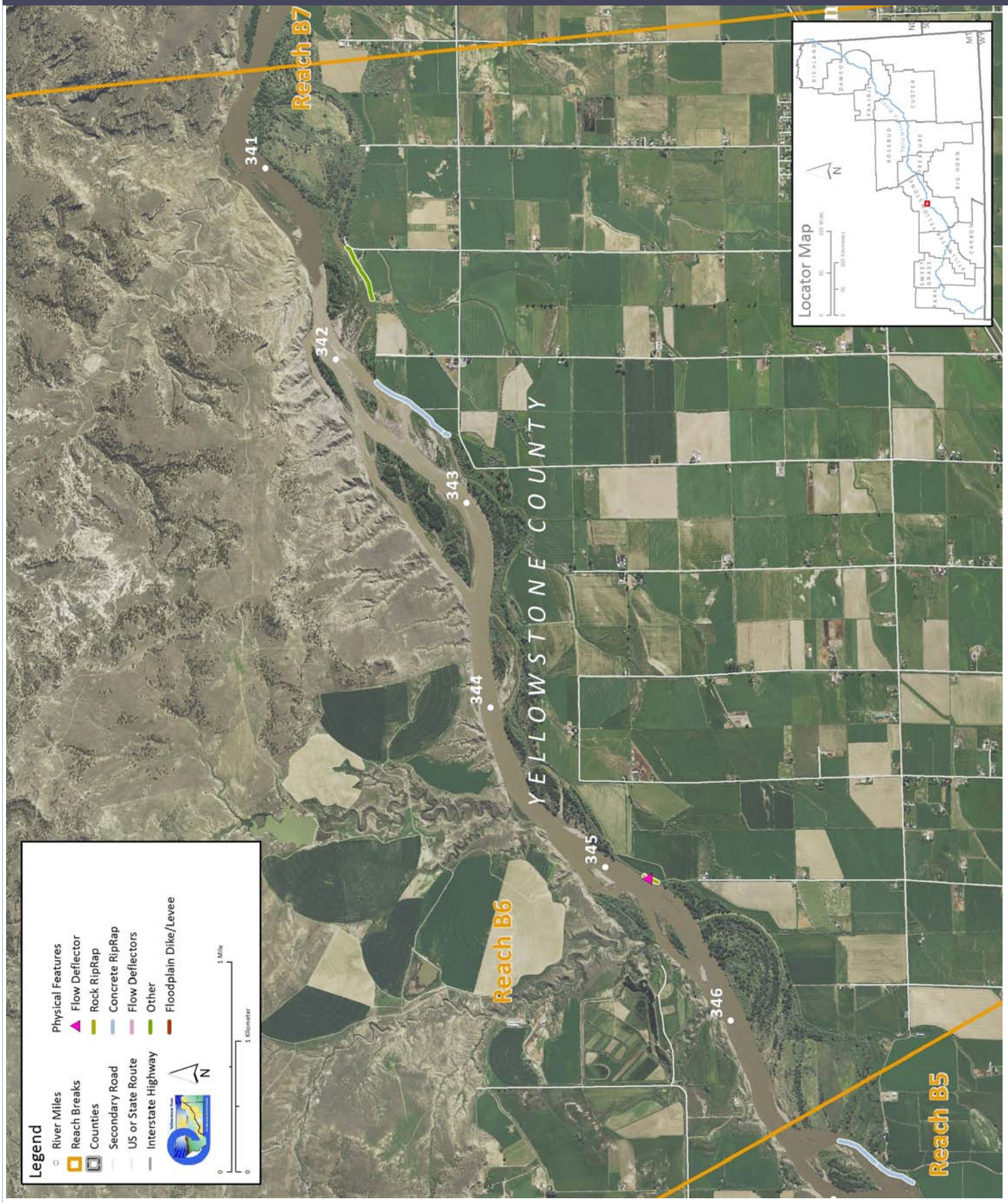
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 26,000 cfs to 21,100 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped from 48,300 cfs to 43,000 cfs, which is a reduction of 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,000 cfs to 2,050 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

Because of the flow alterations, about 25 percent of the 5-year floodplain has become isolated in Reach B6. Much of that 5-year floodplain isolation is within old swales on the south side of the river. The 5-year flood discharge has dropped by 8.25 percent in this reach due to human influences, primarily irrigation.

CEA-Related observations in Reach B6 include:
•Gain in anabranching channel length
•Ice jamming
•Side channel blockage at RM 343.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B6 include:
•Russian olive removal
•Nutrient management at corrals associated with animal handling facility at RM 534.5R

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	156.6	17.7

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	26,000	48,300	59,400	66,200	79,900	85,300	97,700	3,000	3,846
Regulated	21,100	43,000	54,500	61,700	76,300	82,200	95,800	2,050	2,227
% Change	-18.85%	-10.97%	-8.25%	-6.80%	-4.51%	-3.63%	-1.94%	-31.67%	-42.10%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	15-May-51	B/W	1:28,400	6214500	11500
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	8/10/96 - 8/24/96	B/W		6214500	4500
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	15-May-04	Color	1:15,840	6214500	5960
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2005	NAIP	07/12/2005	color	1-meter pixels	6214500	12600
2009	NAIP	7/5/2009	Color	1-meter pixels	6214500	23800
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/24/2011	Color	1-meter pixels	6214500	22800
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	0	0.0%	304	0.5%	304
	Flow Deflectors	0	0.0%	23	0.0%	23
	Concrete RipRap	2,169	3.3%	2,275	3.5%	106
	Car Bodies	1,465	2.3%	1,465	2.3%	0
	Feature Type Totals	**3,634**	**5.6%**	**4,067**	**6.3%**	**433**
	Reach Totals	**3,634**	**5.6%**	**4,067**	**6.3%**	**433**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Car Bodies	984	0	482	0	0	0	0	0
Concrete RipRap	2,168	0	0	0	0	0	0	0
Totals	**3,152**	**0**	**482**	**0**	**0**	**0**	**0**	**0**

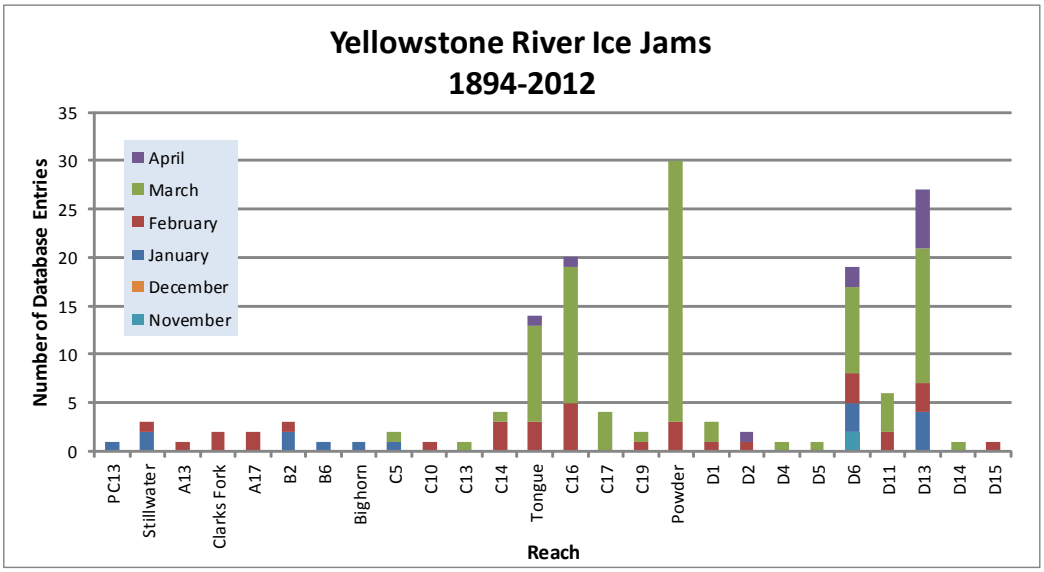
Bankline/Floodplain Inventory: Time Series

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

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	11,978	12,535	12,865	12,865	12,865	12,865
	Totals	**11,978**	**12,535**	**12,865**	**12,865**	**12,865**	**12,865**
Stream Stabilization							
	Concrete RipRap	0	0	2,981	2,981	2,981	2,981
	Car Bodies	0	1,702	1,702	1,702	1,702	1,702
	Totals	**0**	**1,702**	**4,683**	**4,683**	**4,683**	**4,683**
Transportation Encroachment							
	County Road	3,755	3,755	3,755	3,755	3,755	3,755
	Totals	**3,755**	**3,755**	**3,755**	**3,755**	**3,755**	**3,755**

ICE JAMS

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



Jam Date	Jam Type	River Mile	Damages
1/3/1997	NA	345	Severe flooding, evacuations

GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	31,548	26,855	1.85	1950 to 1976:	14.45%
1976	32,976	36,892	2.12	1976 to 1995:	-5.93%
1995	32,692	32,470	1.99	1995 to 2001:	18.16%
2001	32,409	43,922	2.36	1950 to 2001:	27.22%
Change 1950 - 2001	**861**	**17,067**	**0.50**		

Length of Side Channels Blocked

Pre-1950s (ft)	1,352
Post-1950s (ft)	0

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	209	11.4%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1621		1659	
Total Floodplain Area (Ac)	1830		2002	
Total Isolated (Ac)	**209**	**11.4%**	**344**	**24.8%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	304	0	0	**304**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
425	850	1,464	128	9%	123	0	0%

2011 Restricted Migration Area Summary

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

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Irrigated	0	0.0%
RipRap			
	Irrigated	141	8.8%
	Totals	**142**	**8.8%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
236.8	0.0	0.0	0.0	3.6

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	52	65	97	137	1.1%	1.4%	2.1%	3.0%
	Totals	**52**	**65**	**97**	**137**	**1.1%**	**1.4%**	**2.1%**	**3.0%**
Agricultural Land									
	Non-Irrigated	2,365	2,208	1,811	1,737	51.1%	47.7%	39.1%	37.5%
	Irrigated	1,318	1,458	1,946	1,958	28.5%	31.5%	42.0%	42.3%
	Totals	**3,683**	**3,666**	**3,757**	**3,695**	**79.5%**	**79.2%**	**81.1%**	**79.8%**
Channel									
	Channel	879	882	760	778	19.0%	19.1%	16.4%	16.8%
	Totals	**879**	**882**	**760**	**778**	**19.0%**	**19.1%**	**16.4%**	**16.8%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	17	17	17	17	0.4%	0.4%	0.4%	0.4%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**17**	**17**	**17**	**17**	**0.4%**	**0.4%**	**0.4%**	**0.4%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	4	0.0%	0.0%	0.0%	0.1%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**4**	**0.0%**	**0.0%**	**0.0%**	**0.1%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	96	96	0.0%	0.0%	2.6%	2.6%	0.0%	2.6%	0.0%	2.6%
	Flood	1,318	1,458	1,849	1,862	35.8%	39.8%	49.2%	50.4%	4.0%	9.5%	1.2%	14.6%
	Totals	**1,318**	**1,458**	**1,946**	**1,958**	**35.8%**	**39.8%**	**51.8%**	**53.0%**	**4.0%**	**12.0%**	**1.2%**	**17.2%**

Non-Irrigated

Multi-Use	1,683	1,584	1,725	1,675	45.7%	43.2%	45.9%	45.3%	-2.5%	2.7%	-0.6%	-0.4%
Hay/Pasture	682	624	87	61	18.5%	17.0%	2.3%	1.7%	-1.5%	-14.7%	-0.6%	-16.9%
Totals	**2,365**	**2,208**	**1,811**	**1,737**	**64.2%**	**60.2%**	**48.2%**	**47.0%**	**-4.0%**	**-12.0%**	**-1.2%**	**-17.2%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	1.1	1.0	0.5	1.5	0.9	0.4	1.2	0.7	0.7
Max	81.4	33.0	110.7	96.3	139.5	147.3	28.0	98.0	22.3
Average	10.2	7.0	13.4	34.6	24.9	20.5	10.6	20.1	8.9
Sum	194.0	104.9	255.5	380.5	373.4	349.0	84.5	161.0	53.5

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	179.5
Channel to Riparian (acres)	143.0
Riparian Encroachment (acres)	**-36.5**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	156.8
1950s Floodplain Mapped as 2011 Channel (Ac)	89.2
Total Recruitment (1950s to 2011)(Ac)	**246.0**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	2.9	71.5	38.0	0.0	**112.4**
Acres/Valley Mile	0.5	12.7	6.7	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	48.71	2.83%	15.00	0.55	10.97	11.24

FISHERIES SUMMARY

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

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

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

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

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	214.4	115.9	15.3%
Rip Rap Bottom	5.8	5.5	0.7%
Bluff Pool	82.9	57.4	7.6%
Secondary Channel	69.6	21.4	2.8%
Secondary Channel (Seasonal)	137.6	104.6	13.8%
Channel Crossover	107.5	68.4	9.0%
Point Bar		44.5	5.9%
Side Bar		57.1	7.5%
Mid-channel Bar		40.7	5.4%
Island	141.8	144.3	19.0%
Dry Channel		99.8	13.1%

AVIAN

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

Bird Species Observed in Reach/Region

Species of Concern | Potential Species of Concern

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

Yellowstone River Reach Narratives — Reach B7

County	Yellowstone	**Upstream River Mile**	340.6
Classification	UB: Unconfined braided	**Downstream River Mile**	331.8
General Location	To Pompey's Pillar	**Length**	8.80 mi (14.16 km)
General Comments	Unconfined reach		

Narrative Summary

Reach B7 is located just upstream of Pompey's Pillar. The Reach is almost nine miles long and is currently largely unconfined with a primary channel thread and numerous mid-channel bars and point bars. In the 1950's, the main channel flowed more closely along the north valley wall; southward migration since that time has reduced the influence of the valley wall on stream geomorphology. The valley is wide in this area, which is typical where the bounding rock units are made up of the relatively erodible Cretaceous-age Bearpaw shale.

Only 290 feet of the streambank in Reach B7 is armored, and no side channels have been blocked.

Land uses in the reach are primarily agricultural, with about 1,340 acres of flood irrigated land mapped as of 2011. The Channel Migration Zone (CMZ) has been developed for primarily flood irrigation; as of 2011, there were 390 acres of flood irrigated land in the CMZ, and about 4 percent of the total CMZ footprint has become restricted by bank armor and road prisms. The modern 5-year floodplain contains over 275 acres of flood-irrigated ground.

Reach B7 shows major southward migration of the river since 1950, with one area experiencing over 1,600 feet of migration over the past 60 years. The river has gained length, and the valley wall influence has become much less prevalent, as virtually all migration in this and adjacent reaches has been to the south. Since 1950 this section of river has lost almost 20,000 feet of anabranching channel length, and there is no strong indication that this loss is directly associated with floodplain dikes. Rather, it appears that significant lengths of anabranching channels were passively abandoned, which may be the consequence of a 19 percent reduction in the mean annual flood due to human influences.

South of the river over 600 acres of historic 100-year floodplain have been isolated from the river by the railroad. This includes a very broad area between the railroad and Interstate that will likely remain isolated since it is over 3,000 feet from the modern river. This area represents 22 percent of the total historic 100-year floodplain area.

The mouth of Arrow Creek is in Reach B7, and the lower portion of the creek has been captured by the river, shortening the tributary and likely driving downcutting upstream.

Reach B7 has 56 mapped acres of Russian olive that can be found in dense stands, however the extensive lateral migration of the river has promoted extensive recruitment of new woody riparian habitat. Since the 1950s there has been about 640 acres of riparian recruitment in the reach. The acreage of recruitment has exceeded that of erosion of riparian areas by 131 acres. Additionally, there are 260 mapped wetlands in the reach, including 135 acres of wet meadows and marsh.

Reach B7 was sampled as part of the avian study. The average species richness in this reach was 8.8, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. One bird species identified by the Montana Natural Heritage Program as a Potential Species of Concern (PSOC) was identified, the Dickscissel. Another species identified as a Species of Concern (SOC) was identified, the Red-headed Woodpecker.

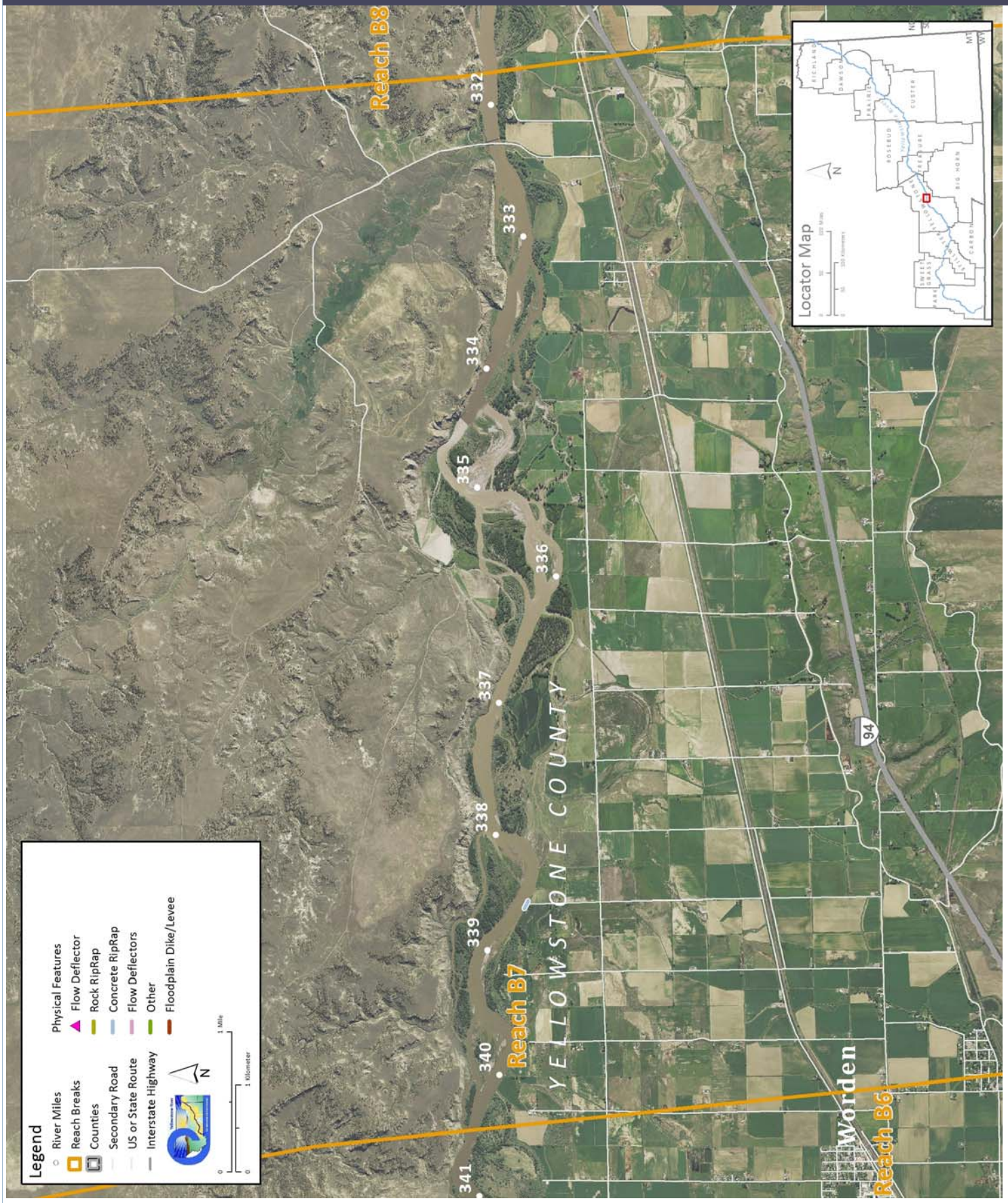
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 27,200 cfs to 22,100 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,010 cfs to 2,060 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

Because of the flow alterations, about 28 percent of the 5-year floodplain has become isolated in Reach B7. Much of that 5-year floodplain isolation is within irrigated fields on the south side of the river.

CEA-Related observations in Reach B7 include:
•Migration away from valley wall resulting in loss of bluff pool habitat.
•Passive abandonment of anabranching channels likely associated with reduced mean annual flows.
•Rapid channel migration through cleared, often flood irrigated fields.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B7 include:
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Billings

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	147.8	23.8

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	27,200	50,400	62,000	69,000	83,100	88,800	102,000	3,010	3,846
Regulated	22,100	44,900	56,900	64,300	79,400	85,600	100,000	2,060	2,227
% Change	-18.75%	-10.91%	-8.23%	-6.81%	-4.45%	-3.60%	-1.96%	-31.56%	-42.10%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	NARA	July 9-27, 1950	B/W		6214500	29500
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	24-Aug-96	B/W		6214500	4350
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	15-May-04	Color	1:15,840	6214500	5960
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2005	NAIP	07/12/2005	color	1-meter pixels	6214500	12600
2005	NAIP	07/09/2005	color	1-meter pixels	6214500	11100
2009	NAIP	7/5/2009	Color	1-meter pixels	6214500	23800
2009	NAIP	6/29/2009	Color	1-meter pixels	6214500	26200
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/24/2011	Color	1-meter pixels	6214500	22800
2011	NAIP	7/16/2011	Color	1-meter pixels	6214500	36000
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Concrete RipRap	289	0.3%	289	0.3%	0
	Feature Type Totals	**289**	**0.3%**	**289**	**0.3%**	**0**
	Reach Totals	**289**	**0.3%**	**289**	**0.3%**	**0**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	0	0	289	0	0	0	0	0
Totals	**0**	**0**	**289**	**0**	**0**	**0**	**0**	**0**

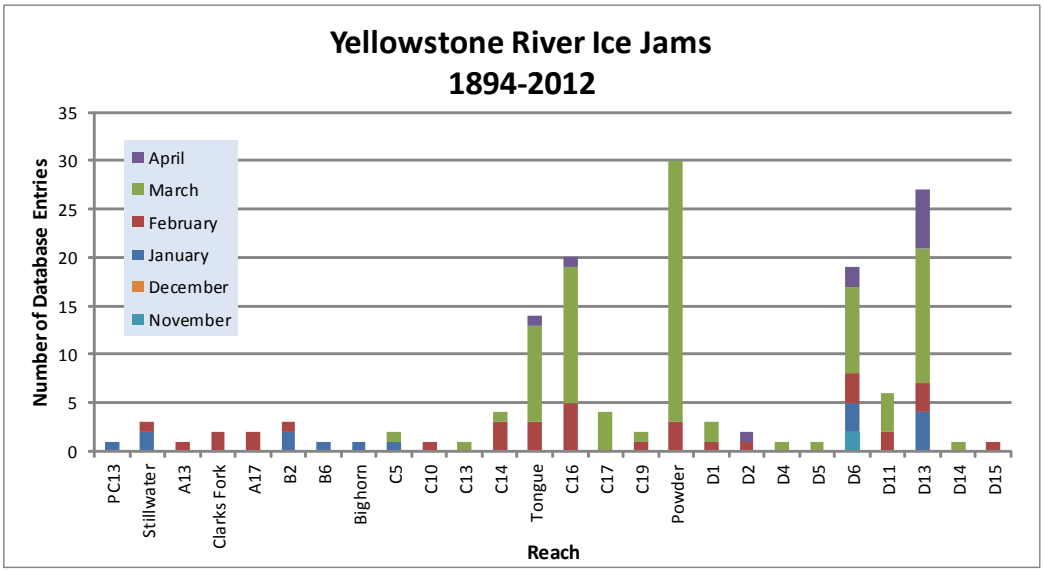
Bankline/Floodplain Inventory: Time Series

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

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	7,487	7,487	7,487	7,487	7,487	7,487
	Totals	**7,487**	**7,487**	**7,487**	**7,487**	**7,487**	**7,487**
Other Off Channel							
	Floodplain Dike/Levee	1,296	2,794	2,794	2,794	2,794	2,794
	Totals	**1,296**	**2,794**	**2,794**	**2,794**	**2,794**	**2,794**
Stream Stabilization							
	Rock RipRap	240	240	511	692	692	692
	Concrete RipRap	0	0	428	1,147	1,619	1,619
	Totals	**240**	**240**	**939**	**1,839**	**2,311**	**2,311**
Transportation Encroachment							
	Other	685	685	685	685	685	685
	County Road	2,068	2,068	2,068	2,068	2,068	2,068
	Bridge Approach	2,731	2,731	2,731	4,064	4,064	4,064
	Totals	**5,485**	**5,485**	**5,485**	**6,818**	**6,818**	**6,818**

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	44,372	71,314	2.61	1950 to 1976:	-1.11%
1976	42,962	67,805	2.58	1976 to 1995:	-25.15%
1995	45,882	42,659	1.93	1995 to 2001:	11.34%
2001	45,770	52,567	2.15	1950 to 2001:	-17.59%
Change 1950 - 2001	**1,398**	**-18,747**	**-0.46**		

Length of Side Channels Blocked

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

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	95	3.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	604	18.9%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	2492		2497	
Total Floodplain Area (Ac)	3191		3108	
Total Isolated (Ac)	**699**	**21.9%**	**611**	**27.9%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	278	0	0	**278**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
665	1,330	2,965	125	4%	4	0	0%

2011 Restricted Migration Area Summary

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

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	105	3.5%
RipRap			
	Irrigated	20	0.7%
	Totals	**125**	**4.2%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
389.1	0.0	0.0	23.5	9.5

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	61	139	170	188	0.9%	2.2%	2.6%	2.9%
	Totals	**61**	**139**	**170**	**188**	**0.9%**	**2.2%**	**2.6%**	**2.9%**
Agricultural Land									
	Non-Irrigated	3,434	3,221	3,341	3,052	53.3%	50.0%	51.9%	47.4%
	Irrigated	1,212	1,656	1,604	1,339	18.8%	25.7%	24.9%	20.8%
	Totals	**4,647**	**4,876**	**4,946**	**4,392**	**72.1%**	**75.7%**	**76.8%**	**68.2%**
Channel									
	Channel	1,681	1,371	1,256	1,742	26.1%	21.3%	19.5%	27.1%
	Totals	**1,681**	**1,371**	**1,256**	**1,742**	**26.1%**	**21.3%**	**19.5%**	**27.1%**
ExUrban									
	ExUrban Other	0	0	14	23	0.0%	0.0%	0.2%	0.4%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	35	0.0%	0.0%	0.0%	0.5%
	Totals	**0**	**0**	**14**	**58**	**0.0%**	**0.0%**	**0.2%**	**0.9%**
Transportation									
	Public Road	45	45	46	51	0.7%	0.7%	0.7%	0.8%
	Interstate	0	1	1	1	0.0%	0.0%	0.0%	0.0%
	Railroad	9	9	9	9	0.1%	0.1%	0.1%	0.1%
	Totals	**54**	**54**	**55**	**61**	**0.8%**	**0.8%**	**0.9%**	**0.9%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	1,212	1,656	1,604	1,339	26.1%	34.0%	32.4%	30.5%	7.9%	-1.5%	-1.9%	4.4%
	Totals	**1,212**	**1,656**	**1,604**	**1,339**	**26.1%**	**34.0%**	**32.4%**	**30.5%**	**7.9%**	**-1.5%**	**-1.9%**	**4.4%**

Non-Irrigated

Multi-Use	2,874	2,580	2,845	2,492	61.9%	52.9%	57.5%	56.7%	-8.9%	4.6%	-0.8%	-5.1%
Hay/Pasture	560	640	497	561	12.0%	13.1%	10.0%	12.8%	1.1%	-3.1%	2.7%	0.7%
Totals	**3,434**	**3,221**	**3,341**	**3,052**	**73.9%**	**66.0%**	**67.6%**	**69.5%**	**-7.9%**	**1.5%**	**1.9%**	**-4.4%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.3	0.3	0.6	0.5	0.8	1.1	1.2	0.4	0.8
Max	41.4	31.7	138.4	100.5	65.7	50.9	80.8	107.7	57.6
Average	6.7	7.3	14.1	16.6	17.5	14.5	14.3	14.0	16.1
Sum	308.9	301.0	535.6	430.9	333.4	420.4	272.3	419.0	160.9

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	277.6
Channel to Riparian (acres)	408.4
Riparian Encroachment (acres)	**130.8**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	414.1
1950s Floodplain Mapped as 2011 Channel (Ac)	222.4
Total Recruitment (1950s to 2011)(Ac)	**636.5**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	11.1	135.1	110.7	0.0	**256.9**
Acres/Valley Mile	1.5	17.8	14.6	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	55.68	2.17%	20.65	0.31	26.47	9.33

FISHERIES SUMMARY

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

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

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

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

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	362.1	182.9	14.6%
Rip Rap Bottom	54.7	20.9	1.7%
Bluff Pool	24.3	21.6	1.7%
Secondary Channel		16.8	1.3%
Secondary Channel (Seasonal)	223.8	163.8	13.0%
Channel Crossover	246.9	112.9	9.0%
Point Bar		152.4	12.1%
Side Bar		87.3	7.0%
Mid-channel Bar		40.2	3.2%
Island	344.0	344.0	27.4%
Dry Channel		113.0	9.0%

AVIAN

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

Bird Species Observed in Reach/Region

Species of Concern | Potential Species of Concern

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

Yellowstone River Reach Narratives — Reach B8

County	Yellowstone	**Upstream River Mile**	331.8
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	322.7
General Location	Bull Mountain	**Length**	9.10 mi (14.65 km)
General Comments	Pompey's Pillar		

Narrative Summary

Reach B8 is located downstream of Pompey's Pillar. The Reach is 9.1 miles long and is partially confined by the valley wall with numerous forested islands. In the 1950's, the main channel flowed more closely along the north valley wall; southward migration since that time has reduced the influence of the valley wall on stream geomorphology. The valley is wide in this area, which is typical where the bounding rock units are made up of the relatively erodible Cretaceous-age Bearpaw shale.

Just over 3,000 feet of streambank are armored by rock riprap, which is about 3.3 percent of the total bankline. All of the bank armor in the reach is protecting the rail line on the south side of the river. High resolution imagery from fall 2011 indicates that at RM 328 about 570 feet of rock riprap has been flanked on the right bank against the rail line, and that the flanked rock is about 80 feet into the river off of the south bank. Currently, the river is within 100 feet of the rail line and migrating rapidly in that direction.

One side channel that is about 6,200 feet long at RM 326R was blocked prior to 1950.

Land uses in the reach are primarily agricultural, with about 1,240 acres of flood irrigated land mapped as of 2011. There are 124 acres of land in sprinkler and 86 under pivot. The modern 5-year floodplain contains about 250 acres of flood-irrigated ground.

One dump site was mapped on an old swale adjacent to a flood irrigated field at RM 326.5R.

The Channel Migration Zone (CMZ) has been developed for primarily flood irrigation; as of 2011, there were 457 acres of flood irrigated land in the CMZ, and about 7 percent of the total CMZ footprint has become restricted by bank armor and road prisms. The railroad has isolated almost 9 percent of the historic 100-year floodplain in the reach. About 22 percent of the 5-year floodplain has become isolated in Reach B8. Much of that 5-year floodplain isolation is due to transportation infrastructure on the south side of the river.

Similar to Reach B7 upstream, Reach B8 shows major southward migration of the river since 1950, with one area at RM 324.3 experiencing over 1,500 feet of migration over the past 60 years. This southward migration has threatened the rail line at RM 328R.

Overall, the migration rates and floodplain turnover rates have dropped since 1976 from 1.9 acres/valley mile/year from 1950 to 1976 to 1.5 acres/valley mile/year from 1976-2001.

Reach B8 has 91 mapped acres of Russian olive that can be found in dense stands, especially on forested islands. Even so, the extensive lateral migration of the river has promoted extensive recruitment of new woody riparian habitat. Since the 1950s there has been about 600 acres of riparian recruitment in the reach, most of which was riparian colonization of old 1950's channel area. The acreage of recruitment has exceeded that of erosion of riparian areas by 51 acres. Additionally, there are 271 mapped wetlands in the reach, including 147 acres of wet meadows and marsh. The reach contains about 33 wetland acres per valley mile, which is a relatively high value for the Yellowstone River.

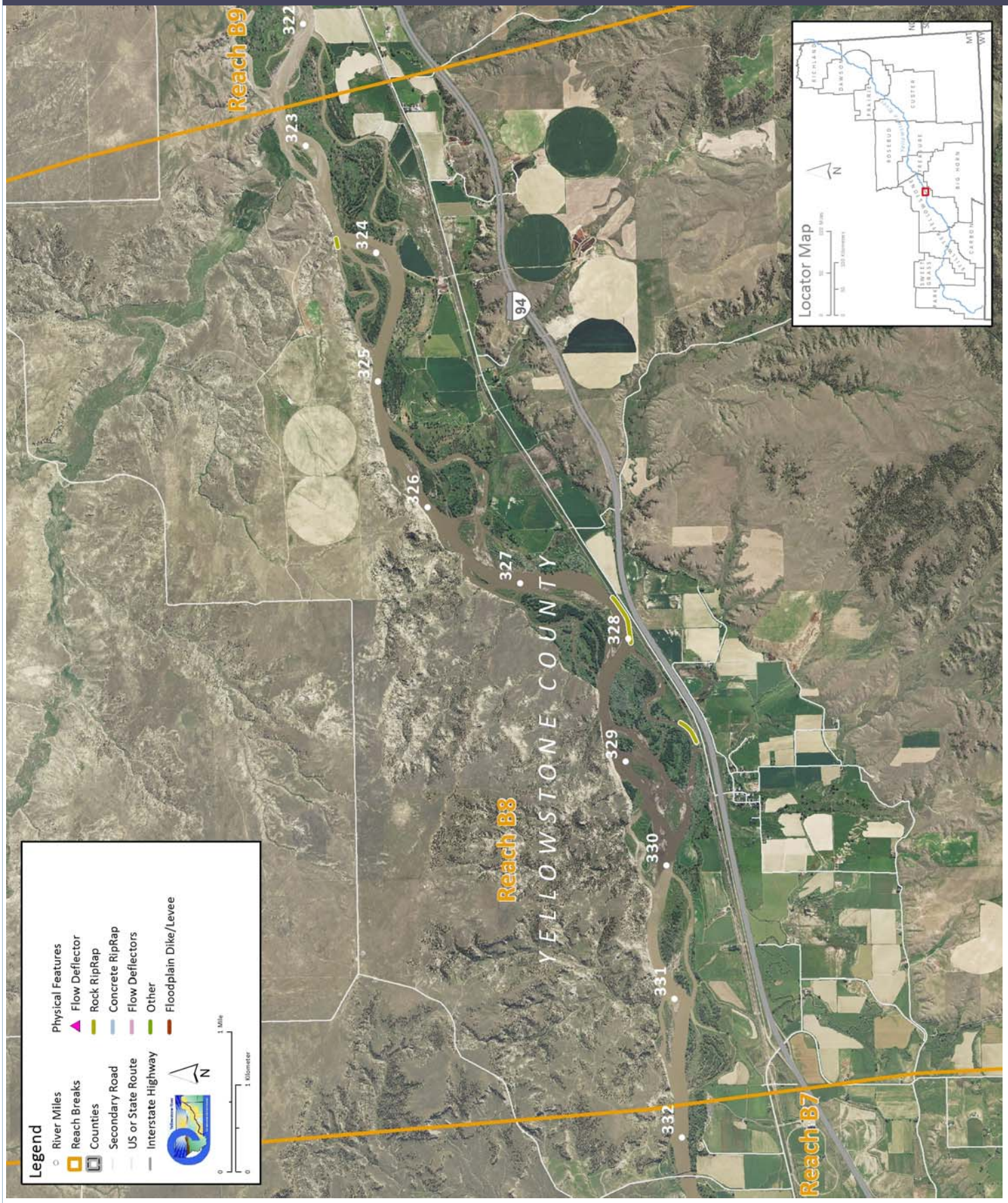
Reach B8 was sampled as part of the avian study. The average species richness in this reach was 7.8, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. One bird species identified by the Montana Natural Heritage Program as a Potential Species of Concern was identified, the Plumbeous Vireo. Another species identified as a Species of Concern was identified, the Red-headed Woodpecker.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 28,000 cfs to 22,800 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,040 cfs to 2,070 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B8 include:
•Migration away from valley wall resulting in loss of bluff pool habitat.
•Blockage of one side channel at RM 326 sometime prior to 1950
•Transportation infrastructure –caused isolation of 5-year floodplain south of the river at RM 329.5

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B8 include:
•Side channel reactivation at RM 326
•Dump removal at RM 326.5R
•Flanked armor removal at RM 328R
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	138.7	32.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	28,000	51,700	63,500	70,700	85,100	90,900	104,000	3,040	3,846
Regulated	22,800	46,100	58,300	65,800	81,300	87,600	102,000	2,070	2,227
% Change	-18.57%	-10.83%	-8.19%	-6.93%	-4.47%	-3.63%	-1.92%	-31.91%	-42.10%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	NARA	July 9-27, 1950	B/W		6214500	29500
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	7/29/96 - 9/11/96	B/W		6214500	10400
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	5/15/04 - 5/14/04	Color	1:15,840	6214500	5960
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2005	NAIP	07/09/2005	color	1-meter pixels	6214500	11100
2009	NAIP	6/29/2009	Color	1-meter pixels	6214500	26200
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/16/2011	Color	1-meter pixels	6214500	36000
2013	NAIP	06/16/2013	color	1-meter pixels	6214500	
2013	NAIP	06/15/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	3,209	3.3%	3,209	3.3%	0
	Feature Type Totals	**3,209**	**3.3%**	**3,209**	**3.3%**	**0**
Floodplain Control						
	Transportation Encroachment	13,957	14.5%	13,957	14.5%	0
	Feature Type Totals	**13,957**	**14.5%**	**13,957**	**14.5%**	**0**
	Reach Totals	**17,166**	**17.8%**	**17,166**	**17.8%**	**0**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	325	338	0	0	0	1,889	0	0
Totals	**325**	**338**	**0**	**0**	**0**	**1,889**	**0**	**0**

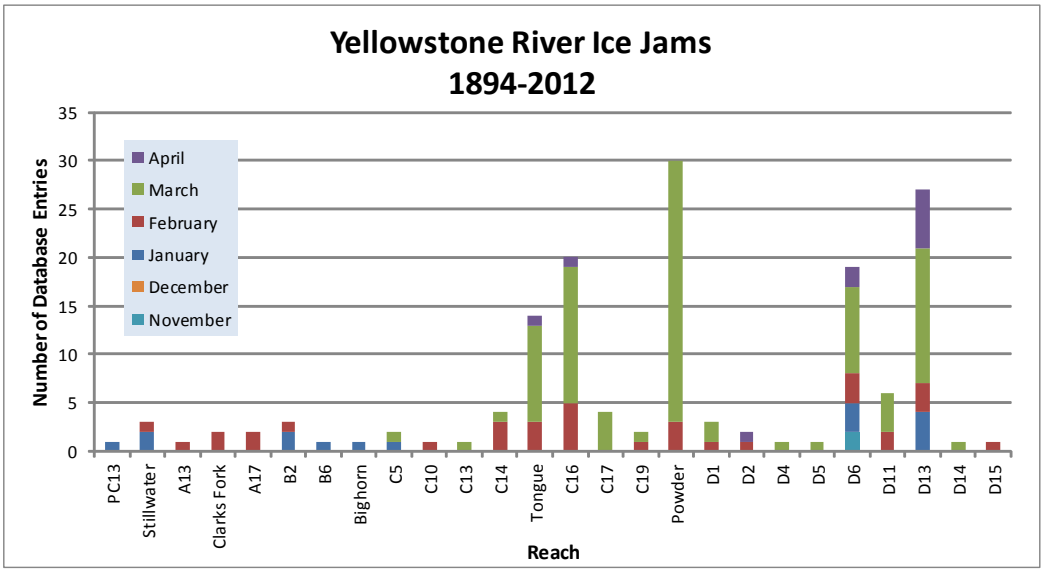
Bankline/Floodplain Inventory: Time Series

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

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	Floodplain Dike/Levee	0	1,314	1,314	1,314	1,314	1,314
	Totals	**0**	**1,314**	**1,314**	**1,314**	**1,314**	**1,314**
Other Off Channel							
	Floodplain Dike/Levee	0	0	2,190	2,190	2,190	2,190
	Totals	**0**	**0**	**2,190**	**2,190**	**2,190**	**2,190**
Stream Stabilization							
	Rock RipRap	1,010	1,489	2,839	2,839	2,839	2,839
	Flow Deflector	0	0	199	199	199	199
	Totals	**1,010**	**1,489**	**3,038**	**3,038**	**3,038**	**3,038**
Transportation Encroachment							
	Railroad	17,269	17,269	17,269	17,269	17,269	17,269
	Interstate	0	11,402	11,402	11,402	11,402	11,402
	Totals	**17,269**	**28,670**	**28,670**	**28,670**	**28,670**	**28,670**

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	51,355	76,381	2.49	1950 to 1976:	-1.05%
1976	46,802	68,389	2.46	1976 to 1995:	11.40%
1995	47,129	82,091	2.74	1995 to 2001:	-7.86%
2001	48,159	73,512	2.53	1950 to 2001:	1.57%
Change 1950 - 2001	**-3,196**	**-2,869**	**0.04**		

Length of Side Channels Blocked

Pre-1950s (ft)	6,209
Post-1950s (ft)	0

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	219	8.7%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	2310		2696	
Total Floodplain Area (Ac)	2530		3138	
Total Isolated (Ac)	**219**	**8.7%**	**442**	**21.6%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	251	0	0	**251**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
515	1,031	3,175	224	7%	63	0	0%

2011 Restricted Migration Area Summary

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	224	6.9%
	Totals	**224**	**6.9%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
456.7	2.7	0.0	3.8	79.8

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		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	91	105	126	123	1.3%	1.5%	1.8%	1.8%
	Totals	**91**	**105**	**126**	**123**	**1.3%**	**1.5%**	**1.8%**	**1.8%**
Agricultural Land									
	Non-Irrigated	3,613	3,313	3,245	3,057	52.2%	47.9%	46.9%	44.2%
	Irrigated	1,276	1,349	1,386	1,449	18.4%	19.5%	20.0%	20.9%
	Totals	**4,889**	**4,663**	**4,632**	**4,506**	**70.6%**	**67.4%**	**66.9%**	**65.1%**
Channel									
	Channel	1,793	1,853	1,863	1,979	25.9%	26.8%	26.9%	28.6%
	Totals	**1,793**	**1,853**	**1,863**	**1,979**	**25.9%**	**26.8%**	**26.9%**	**28.6%**
ExUrban									
	ExUrban Other	0	0	0	2	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	43	64	64	75	0.6%	0.9%	0.9%	1.1%
	Totals	**43**	**64**	**64**	**77**	**0.6%**	**0.9%**	**0.9%**	**1.1%**
Transportation									
	Public Road	58	63	63	63	0.8%	0.9%	0.9%	0.9%
	Interstate	0	126	126	126	0.0%	1.8%	1.8%	1.8%
	Railroad	47	47	46	46	0.7%	0.7%	0.7%	0.7%
	Totals	**105**	**236**	**235**	**235**	**1.5%**	**3.4%**	**3.4%**	**3.4%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		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	6	64	124	124	0.1%	1.4%	2.7%	2.8%	1.2%	1.3%	0.1%	2.6%
	Pivot	0	86	86	86	0.0%	1.8%	1.9%	1.9%	1.8%	0.0%	0.1%	1.9%
	Flood	1,270	1,200	1,176	1,239	26.0%	25.7%	25.4%	27.5%	-0.2%	-0.3%	2.1%	1.5%
	Totals	**1,276**	**1,349**	**1,386**	**1,449**	**26.1%**	**28.9%**	**29.9%**	**32.2%**	**2.8%**	**1.0%**	**2.2%**	**6.1%**

Non-Irrigated

Multi-Use	3,149	2,837	2,824	2,691	64.4%	60.8%	61.0%	59.7%	-3.6%	0.1%	-1.2%	-4.7%
Hay/Pasture	464	476	422	366	9.5%	10.2%	9.1%	8.1%	0.7%	-1.1%	-1.0%	-1.4%
Totals	**3,613**	**3,313**	**3,245**	**3,057**	**73.9%**	**71.1%**	**70.1%**	**67.8%**	**-2.8%**	**-1.0%**	**-2.2%**	**-6.1%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.3	0.5	0.9	0.6	0.8	0.7	1.4	1.8	2.9
Max	72.9	79.9	93.2	105.1	72.0	115.3	91.2	47.9	96.4
Average	11.4	9.2	16.0	14.8	18.9	26.8	22.4	14.2	23.0
Sum	434.1	388.1	432.9	489.6	490.4	590.2	336.0	312.8	322.4

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	378.2
Channel to Riparian (acres)	428.7
Riparian Encroachment (acres)	**50.5**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	432.2
1950s Floodplain Mapped as 2011 Channel (Ac)	165.3
Total Recruitment (1950s to 2011)(Ac)	**597.4**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	10.3	147.4	113.7	0.0	**271.4**
Acres/Valley Mile	1.3	18.8	14.5	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	91.16	3.23%	25.56	2.82	24.25	30.93

FISHERIES SUMMARY

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

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

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

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

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	247.6	121.5	6.5%
Rip Rap Bottom	82.7	24.2	1.3%
Bluff Pool	148.1	88.7	4.8%
Secondary Channel	110.2	42.9	2.3%
Secondary Channel (Seasonal)	392.6	227.2	12.2%
Channel Crossover	155.4	101.5	5.4%
Point Bar		66.2	3.6%
Side Bar		115.4	6.2%
Mid-channel Bar		82.8	4.4%
Island	768.7	774.6	41.6%
Dry Channel		219.0	11.7%

AVIAN

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

Bird Species Observed in Reach/Region

Species of Concern | Potential Species of Concern

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Yellowstone	**Upstream River Mile**	322.7
Classification	UA: Unconfined anabranching	**Downstream River Mile**	318
General Location	Reed Creek	**Length**	4.70 mi (7.56 km)
General Comments	Meander cutoff isolated by railroad		

Narrative Summary

Reach B9 is located in lower Yellowstone County near Reed Creek. The Reach is 4.7 miles long and is an Unconfined Anabranching (UA) reach type, indicating the presence of extensive forested islands with little valley wall influence on the main channel. This reach type is typically the most dynamic in the system due to a lack of confinement and extent of side channels.

About 7,300 feet of streambank are armored by rock riprap, which is about 15 percent of the total bankline. Most of the bank armor in the reach is protecting the rail line on the south side of the river, and most of it is located along the edge of a section of bluff line. Another section of armor is protecting a major power line crossing on the north bank at RM 321. Currently, two towers on the crossing are right on the edge of the river.

One side channel that is about 8,000 feet long at RM 321.5L was blocked prior to 1950. The lower end of this old channel still holds open water, but the upstream end has been graded into fields and also supports two major power line towers.

Land uses related to both irrigation and the railroad have encroached into the Channel Migration Zone (CMZ) in Reach B9. Overall, land uses in the reach are primarily agricultural, with about 508 acres of flood irrigated land mapped as of 2011. About half of that irrigated acreage is within the CMZ. There are 384 acres under pivot, about 75 of which are within the CMZ. The railroad has encroached into 101 acres of the CMZ and is primarily responsible for its isolation. In total, just under 10 percent of the CMZ has been restricted due to bank armor, and 7.3 percent of the restriction is due to the railroad, while 2.4 percent is associated with the protection of irrigated lands.

The modern 5-year floodplain contains about 76 acres of flood-irrigated ground, and 64 acres of ground under pivot.

Waco-Custer Diversion Dam is located at RM 320. The Waco-Custer ditch company was formed in the early 1900's, and the diversion dam was constructed shortly thereafter (http://www.fws.gov/YellowstoneRiverCoordinator/Waco-custer.html). The Waco-Custer diversion supports approximately 4,300 acres of irrigation, with a diversion capacity of 125 cfs. The structure is located approximately eight miles west of Custer, at River Mile 320. At the diversion, the Yellowstone River flows through two main channels, and the structure itself blocks only the right channel. The structure feeds the Waco-Custer Canal, which flows on the south floodplain surface of the Yellowstone River.

Migration rates in several locations in Reach B9 have exceeded an average of 10 feet per year since the mid-1950s. At Rm 322, the river migrated almost 200 feet between 2001 and 2011, which is double that average rate of 10 feet per year. That rapid recent migration has been through irrigated fields on the south side of the river. Lateral migration of the river has promoted extensive recruitment of new woody riparian habitat. Since the 1950s there has been about 210 acres of riparian recruitment in the reach, most of which was riparian colonization of old 1950's channel area. Additionally, there are 213 mapped wetlands in the reach, including 105 acres of emergent wetland types such as wet meadows and marsh. The reach contains about 53 wetland acres per valley mile, which is a relatively high value for the Yellowstone River.

Reach B9 has had a major loss of forest area that is considered at low risk of cowbird parasitism. In 19590, there were about 48 acres per valley mile of such forest, and that had been reduced by 2001 to 21 acres per valley mile.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 30,200 cfs to 24,500 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,060 cfs to 2,080 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

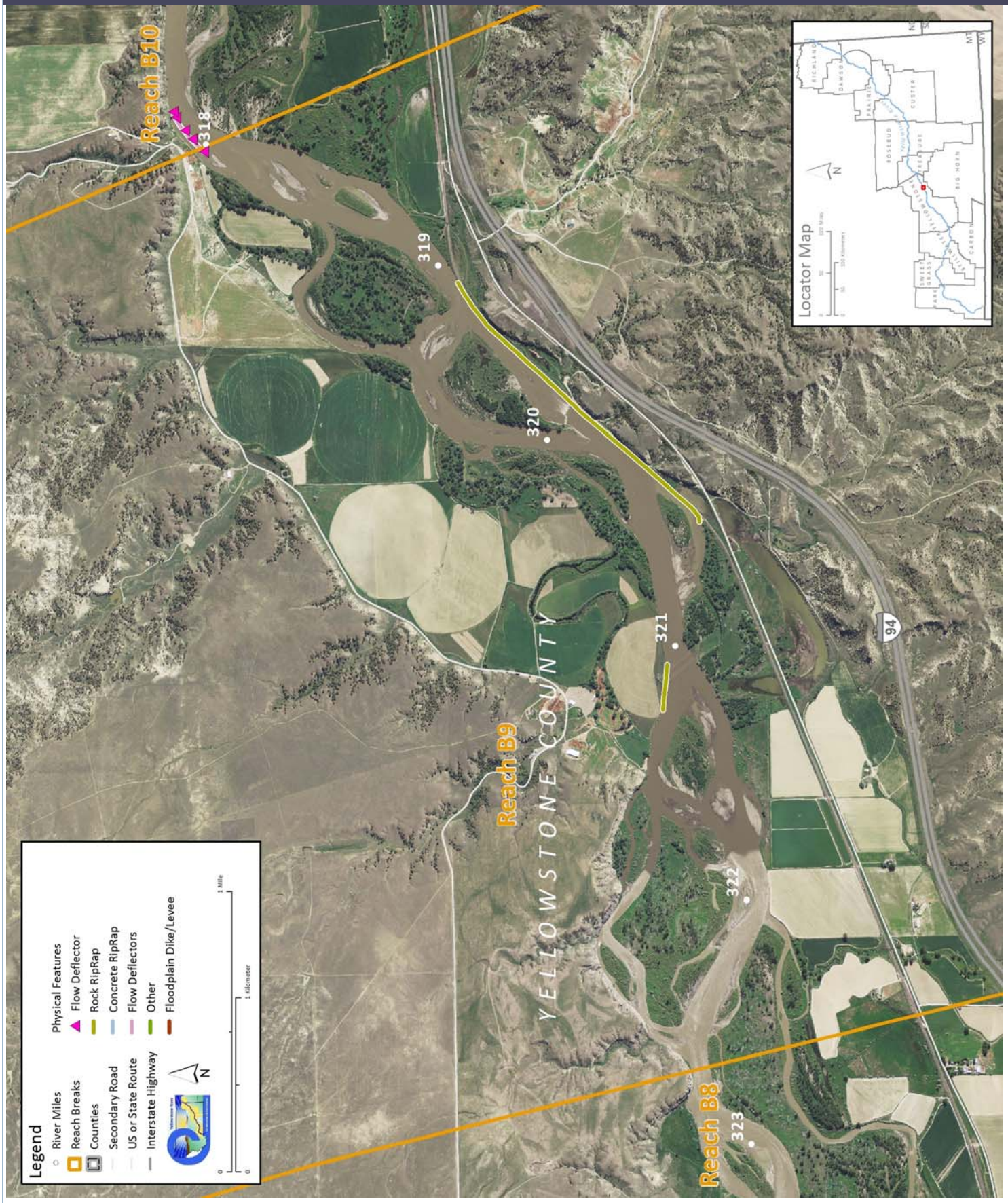
About 23 percent of the 5-year floodplain has become isolated in Reach B9, and the vast majority of this isolation is on the south side of the river at RM 321 where the rail line has isolated an historic side channel. Much of that 5-year floodplain isolation is due to transportation infrastructure on the south side of the river. This isolated floodplain area still holds open water in a distinct swale.

CEA-Related observations in Reach B9 include:
•Blockage of one side channel at RM 321.5 sometime prior to 1950
•Railroad isolation of major channel remnant that supports open water.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B9 include:
•Side channel reactivation at RM 321.5—may be difficult due to power line
•CMZ management due to~10 percent restriction of CMZ
•Russian olive removal
•Floodplain reconnection where active rail line has isolated historic channel remnant at RM 321R.

•Fish passage Practice at Waco Custer Diversion Dam (not complete blockage)
•Watercraft passage Practice at Waco Custer Diversion Dam (side channel passage exists)
•Irrigation Infrastructure management at Waco Custer Diversion Dam.

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Billings

Flood History

Year	Date	Flow on Date	Return Interval
1943	Jun 21	61,200	10-25 yr
1996	Jun 12	61,900	10-25 yr
1944	Jun 27	64,800	10-25 yr
1967	Jun 16	66,100	10-25 yr
1975	Jul 7	67,600	10-25 yr
1974	Jun 19	69,500	25-50 yr
2011	Jul 2	70,600	25-50 yr
1918	Jun 15	78,100	50-100 yr
1997	Jun 12	82,000	>100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	134.0	41.7

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	30,200	55,500	68,100	75,700	91,000	97,200	111,000	3,060	3,846
Regulated	24,500	49,400	62,400	70,400	86,900	93,600	108,800	2,080	2,227
% Change	-18.87%	-10.99%	-8.37%	-7.00%	-4.51%	-3.70%	-1.98%	-32.03%	-42.10%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	NARA	July 9-27, 1950	B/W		6214500	29500
1976	USCOE	29-Sep-76	B/W	1:24,000	6214500	5630
1995	USGS DOQQ	29-Jul-96	B/W		6214500	10400
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6214500	1700
2004	Merrick	14-May-04	Color	16000	6214500	7010
2005	NAIP	07/14/2005	color	1-meter pixels	6214500	9730
2009	NAIP	6/29/2009	Color	1-meter pixels	6214500	26200
2011	USCOE	October 2012	color	1-ft pixel	6214500	3860
2011	NAIP	7/16/2011	Color	1-meter pixels	6214500	36000
2013	NAIP	06/16/2013	color	1-meter pixels	6214500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	7,304	14.9%	7,304	14.9%	0
	Flow Deflectors	18	0.0%	18	0.0%	0
	Between Flow Deflectors	70	0.1%	70	0.1%	0
	Feature Type Totals	**7,393**	**15.1%**	**7,393**	**15.1%**	**0**
Floodplain Control						
	Transportation Encroachment	1,748	3.6%	1,748	3.6%	0
	Feature Type Totals	**1,748**	**3.6%**	**1,748**	**3.6%**	**0**
	Reach Totals	**9,141**	**18.6%**	**9,141**	**18.6%**	**0**

Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	0	0	0	0	0	6,445	0	0
Totals	**0**	**0**	**0**	**0**	**0**	**6,445**	**0**	**0**

Bankline/Floodplain Inventory: Time Series

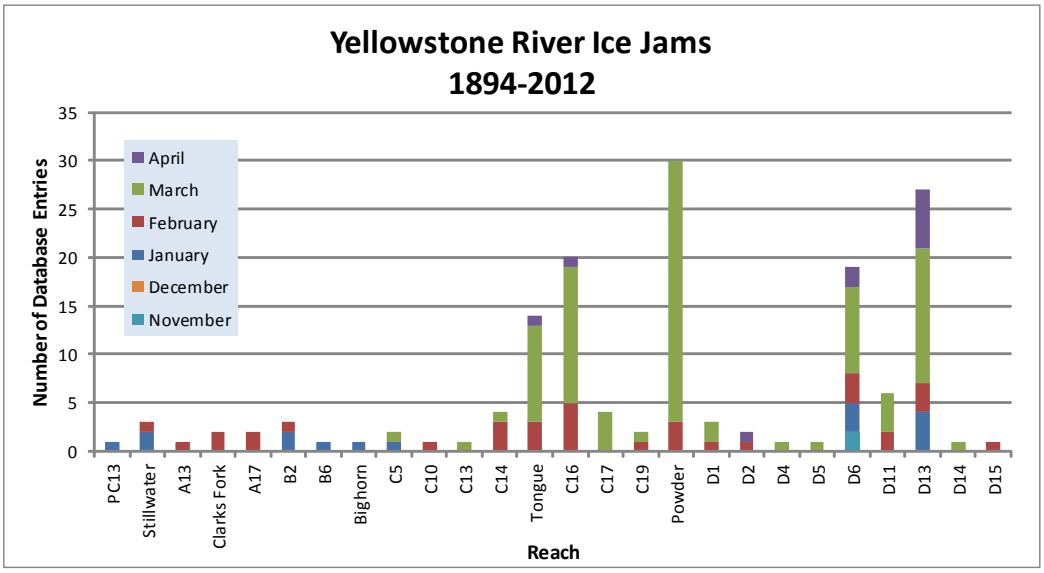
The Human Impacts Timeline assessed physical feature development through time for Yellowstone, Stillwater, and Dawson Counties.

		Sum of Feature Length (ft)					
Feature Class	Feature Type	1950	1976	1995	2001	2004	2005
Irrigation							
	In Channel Diversion	198	198	198	198	198	198
	Floodplain Dike/Levee	2,233	2,233	2,233	2,233	2,233	2,233
	Totals	**2,431**	**2,431**	**2,431**	**2,431**	**2,431**	**2,431**
Other							
	Floodplain Dike/Levee	0	173	173	173	173	173
	Totals	**0**	**173**	**173**	**173**	**173**	**173**
Other Off Channel							
	Floodplain Dike/Levee	1,545	1,545	1,545	1,545	1,545	1,545
	Totals	**1,545**	**1,545**	**1,545**	**1,545**	**1,545**	**1,545**
Stream Stabilization							
	Rock RipRap	6,336	6,448	8,229	8,891	8,891	8,891
	Totals	**6,336**	**6,448**	**8,229**	**8,891**	**8,891**	**8,891**
Transportation Encroachment							
	Railroad	14,094	14,094	14,094	14,094	14,094	14,094
	Interstate	0	1,745	1,745	1,745	1,745	1,745

County Road	6,980	6,980	6,980	6,980	6,980	6,980
Totals	**21,074**	**22,819**	**22,819**	**22,819**	**22,819**	**22,819**

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	23,025	41,519	2.80	1950 to 1976:	8.46%
1976	22,453	45,810	3.04	1976 to 1995:	-20.71%
1995	24,596	34,695	2.41	1995 to 2001:	7.65%
2001	24,510	39,093	2.59	1950 to 2001:	-7.43%
Change 1950 - 2001	**1,485**	**-2,426**	**-0.21**		

Length of Side Channels Blocked

Pre-1950s (ft)	7,943
Post-1950s (ft)	0

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1059		1136	
Total Floodplain Area (Ac)	1059		1311	
Total Isolated (Ac)	**0**	**0.0%**	**175**	**22.7%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	76	0	64	**140**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
525	1,049	1,651	99	6%	82	69	85%

2011 Restricted Migration Area Summary

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

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	101	5.8%
RipRap/Flow Deflectors			
	Other Infrastructure	2	0.1%
RipRap			
	Railroad	26	1.5%
	Irrigated	40	2.3%
	Totals	**169**	**9.7%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
232.1	0.0	74.5	0.6	17.5

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	12	31	58	62	0.3%	0.8%	1.5%	1.6%
	Totals	**12**	**31**	**58**	**62**	**0.3%**	**0.8%**	**1.5%**	**1.6%**
Agricultural Land									
	Non-Irrigated	2,250	2,222	1,841	1,805	58.8%	58.1%	48.1%	47.2%
	Irrigated	657	575	923	892	17.2%	15.0%	24.1%	23.3%
	Totals	**2,906**	**2,797**	**2,763**	**2,697**	**75.9%**	**73.1%**	**72.2%**	**70.5%**
Channel									
	Channel	847	845	852	914	22.1%	22.1%	22.3%	23.9%
	Totals	**847**	**845**	**852**	**914**	**22.1%**	**22.1%**	**22.3%**	**23.9%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	1	1	1	1	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**1**	**1**	**1**	**1**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	38	41	41	41	1.0%	1.1%	1.1%	1.1%
	Interstate	0	88	88	88	0.0%	2.3%	2.3%	2.3%
	Railroad	23	23	23	23	0.6%	0.6%	0.6%	0.6%
	Totals	**61**	**153**	**153**	**153**	**1.6%**	**4.0%**	**4.0%**	**4.0%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	384	0.0%	0.0%	0.0%	14.2%	0.0%	0.0%	14.2%	14.2%
	Flood	657	575	923	508	22.6%	20.7%	33.4%	18.8%	-1.9%	12.7%	-14.6%	-3.8%
	Totals	**657**	**575**	**923**	**892**	**22.6%**	**20.7%**	**33.4%**	**33.1%**	**-1.9%**	**12.7%**	**-0.3%**	**10.5%**

Non-Irrigated

Multi-Use	1,845	1,691	1,752	1,652	63.5%	60.9%	63.4%	61.3%	-2.6%	2.5%	-2.1%	-2.2%
Hay/Pasture	405	511	89	153	13.9%	18.4%	3.2%	5.7%	4.5%	-15.2%	2.5%	-8.3%
Totals	**2,250**	**2,201**	**1,841**	**1,805**	**77.4%**	**79.3%**	**66.6%**	**66.9%**	**1.9%**	**-12.7%**	**0.3%**	**-10.5%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.1	0.4	1.9	0.3	3.5	1.1	0.1	0.0	0.2
Max	33.8	109.4	99.0	100.2	75.8	87.8	41.1	33.8	55.8
Average	6.5	8.8	10.4	19.9	20.5	26.9	15.4	9.9	17.9
Sum	208.0	289.6	270.5	357.8	266.2	269.1	76.9	88.7	161.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	168.9
Channel to Riparian (acres)	175.3
Riparian Encroachment (acres)	**6.4**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	175.8
1950s Floodplain Mapped as 2011 Channel (Ac)	34.9
Total Recruitment (1950s to 2011)(Ac)	**210.7**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	24.3	104.6	83.6	0.0	**212.5**
Acres/Valley Mile	6.2	26.9	21.5	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	5.90	0.27%	0.14	0.58	2.15	1.31

FISHERIES SUMMARY

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

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

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

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

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	164.1	75.4	8.9%
Rip Rap Margin	20.4	11.3	1.3%
Bluff Pool	13.3	6.2	0.7%
Secondary Channel	105.5	22.6	2.7%
Secondary Channel (Seasonal)	85.6	110.1	12.9%
Channel Crossover	127.2	83.4	9.8%
Point Bar		35.4	4.2%
Side Bar		50.6	5.9%
Mid-channel Bar		42.5	5.0%
Island	277.5	317.6	37.3%
Dry Channel		81.6	9.6%
Dam Influenced	16.7	15.0	1.8%

AVIAN

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region B

The study segment Big Horn to Laurel includes data from the people of one large county, Yellowstone County. Three themes dominate conversations with the four interest groups. One theme focuses on the evolving communities of Yellowstone County, most of which are influenced by the economic success and sheer growth of Billings. The second theme focuses on the evolving relationships that the people have with the river. While traditional agricultural activities continue in the county, many people discuss notions related to urban and residential experiences and how the river becomes an asset that improves one's quality of life as an urban dweller. The third theme involves a complex tangle of pressures and demands that require managerial strategies capable of dealing with a future that has arrived.

County	Treasure	**Upstream River Mile**	298.1
Classification	UA: Unconfined anabranching	**Downstream River Mile**	292.3
General Location	From Bighorn confluence	**Length**	5.80 mi (9.33 km)
General Comments	From Bighorn confluence: Includes 1 mile of left bank valley wall control; Extensive bank prot.		

Narrative Summary

Reach C1 is located just downstream of the Bighorn River confluence. The Reach is 5.8 miles long and is an Unconfined Anabranching reach type, (UA), indicating the presence of forested islands with minimal valley wall influence on the river. These reach types tend to be the most dynamic of all reach types, with typically high rates of bank migration. At RM 296.5 for example, the river has migrated over 250 feet to the southeast between 2001 and 2011, indicating an average migration rate of over 25 feet per year.

There are about 2,300 feet of rock riprap in the reach, which collectively armors about 4 percent of the total bankline. About 1,000 feet of armor is protecting the rail line and another 500 feet is protecting agricultural ground. The remainder is protecting the Rancher's Ditch Diversion Structure at RM 295.5.

The Rancher's Ditch diversion dam is located approximately 2.5 miles downstream of the Bighorn River confluence. The dam was constructed in the early part of the 20th century and feeds a canal that flows on the north side of the river. There is a large, vegetated island in the Yellowstone River at the point of diversion, and diversion dams block channels on both sides of the island. The 2011 imagery shows that the south channel is becoming progressively abandoned, so that most flow goes over the main diversion structure on the north channel.

Since 1950, there have been over 7,000 feet of side channel blocked by floodplain dikes in the reach. These channels are on the lower end of the reach on the left (northwest) bank at RM 293. Even though side channels have been blocked, there has been a net gain of side channel length in the reach; since 1950, the total anabranching channel length has increased by 3,800 feet.

Since 1950, Reach C1 has experienced over 300 acres of new riparian recruitment, with most of that colonization occurring in old 1950s channel area. In balancing the amount of riparian area eroded out to the colonization acreage, there has still been a net gain of 118 acres of riparian area associated with channel movement. This reflects erosion of non-wooded lands and colonization of resulting open bar surfaces by woody vegetation, as well as the fact that the channel has gotten smaller since 1950; the bankfull area dropped by almost 50 acres (6 percent) between 1950 and 2001.

Whereas 8 percent of the 100-year floodplain has become isolated due to human development, about 47 percent (633 acres) of the 5-year floodplain is no longer inundated at that frequency. About 80 acres of historic 100-year floodplain area has become isolated by the railroad, and another 42 acres due to flow alterations. The loss of 5-year floodplain shows the strong imprint of flow alterations below the mouth of the Bighorn River and of development of those areas that are less frequently inundated; about 216 acres of currently flood irrigated floodplain areas are in the historic 5-year floodplain footprint.

Land use is dominated by agriculture, with 1,212 acres of pivot irrigation development since 1950. About 15 of those acres of pivot are within the Channel Migration Zone (CMZ). Approximately 7 percent of the Channel Migration Zone (CMZ) has been restricted, with about half of the restrictions due to riprap along the railroad, and the other half due to floodplain dikes protecting irrigated lands.

There are several corrals associated with an animal handling facility at RM 296.8R. The river is migrating in the direction of these corrals and is currently about 600 feet from the facility.

Reach C1 supports over 40 acres per valley mile of mapped wetland, which is a relatively high wetland density for the river. There are also over 100 acres of Russian olive mapped in the reach, occupying 2.6 percent of the total floodplain area.

Reach C1 has seen a substantial loss in forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 48 acres per valley mile of such forest, and that number decreased to 20 acres per valley mile by 2001.

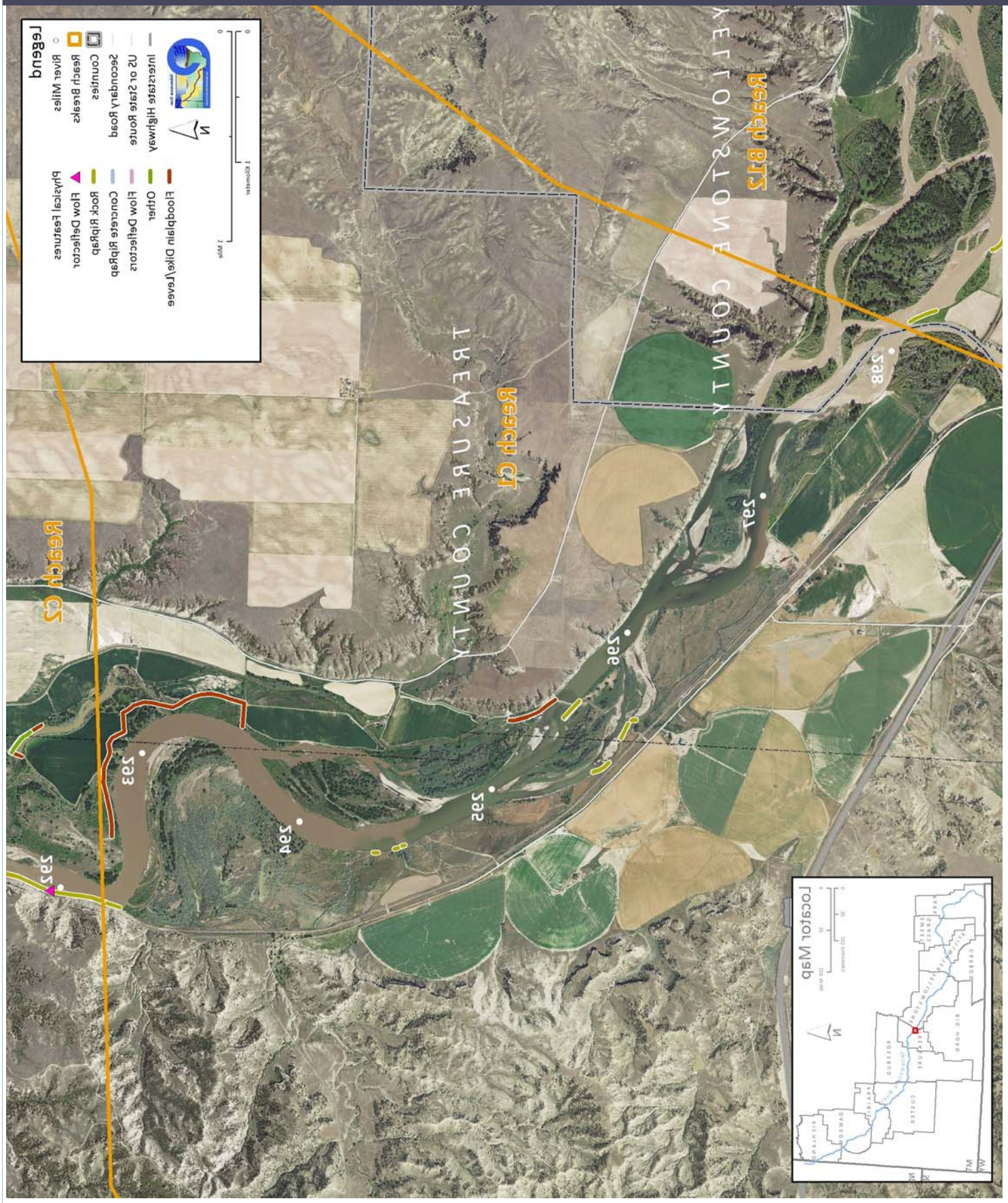
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 60,800 cfs to 47,100 cfs, a drop of about 23 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 20 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,600 cfs to 2,950 cfs with human development, a reduction of 36 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,150 cfs under unregulated conditions to 3,320 cfs under regulated conditions at Reach C10 downstream where the analysis begins, a reduction of 46 percent.

CEA-Related observations in Reach C1 include:
•Blocking of over a mile of side channel by floodplain dikes

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C1 include:
•Fish Passage at Ranchers Ditch Diversion: Structures block two channels at the diversion.
•Watercraft Passage at Ranchers Ditch Diversion
•Irrigation Infrastructure Management at Ranchers Ditch Diversion
•Side channel reactivation at RM 293

•Nutrient management at corrals associated with animal handling facility at RM 296.8R
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	108.3	66.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		60,800	76,600	86,900	110,000	119,000	142,000	4,600	3,846
Regulated		47,100	61,400	70,700	91,200	99,900	121,000	2,950	2,227
% Change		-22.53%	-19.84%	-18.64%	-17.09%	-16.05%	-14.79%	-35.87%	-42.10%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	8-Aug-96	B/W		6295000	9110
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/13/2005	color	1-meter pixels	6309000	17700
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	6/29/2009	Color	1-meter pixels	6309000	42200
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/20/2011	Color	1-meter pixels	6309000	46100
2013	NAIP	07/21/2013	color	1-meter pixels	6309000	
2013	NAIP	07/20/2013	color	1-meter pixels	6309000	
2013	NAIP	06/15/2013	color	1-meter pixels	6309000	
2013	NAIP	06/16/2013	color	1-meter pixels	6309000	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	1,900	3.0%	2,306	3.7%	406
	Feature Type Totals	**1,900**	**3.0%**	**2,306**	**3.7%**	**406**
Floodplain Control						
	Floodplain Dike/Levee	9,038	14.4%	9,038	14.4%	0
	Feature Type Totals	**9,038**	**14.4%**	**9,038**	**14.4%**	**0**
	Reach Totals	**10,938**	**17.5%**	**11,344**	**18.1%**	**406**

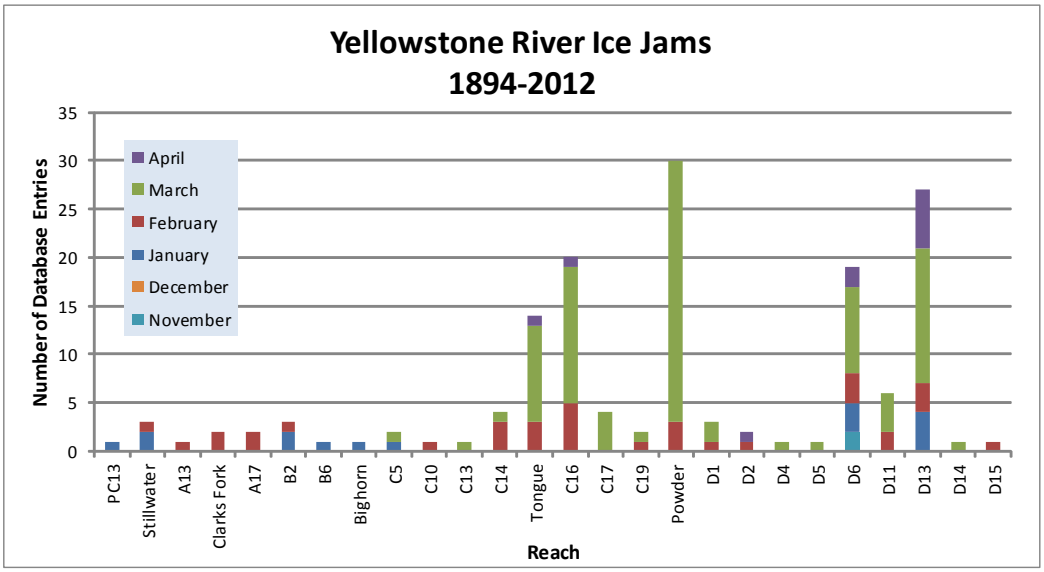
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	0	0	984	0	0	472	0	0
Totals	**0**	**0**	**984**	**0**	**0**	**472**	**0**	**0**

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	31,562	43,000	2.36	1950 to 1976:	8.77%
1976	30,782	48,316	2.57	1976 to 1995:	-6.93%
1995	31,314	43,579	2.39	1995 to 2001:	4.32%
2001	31,294	46,785	2.50	1950 to 2001:	5.62%
Change 1950 - 2001	**-269**	**3,785**	**0.13**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	7,171

HYDRAULICS

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

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

Floodplain Isolation

	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)	42	2.2%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	30	1.6%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	80	4.2%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	1737		1476	
Total Floodplain Area (Ac)	1889		2110	
Total Isolated (Ac)	**152**	**8.1%**	**633**	**45.9%**

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

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:	69	0	0	**69**

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
355	711	1,804	113	6%	162	0	0%

2011 Restricted Migration Area Summary

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

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Railroad	56	2.9%
Dike/Levee			
	Irrigated	57	2.9%
	Totals	**113**	**5.7%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
150.0	0.0	14.5	0.0	10.1

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		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	51	66	54	40	0.9%	1.1%	0.9%	0.7%
	Totals	**51**	**66**	**54**	**40**	**0.9%**	**1.1%**	**0.9%**	**0.7%**
Agricultural Land									
	Non-Irrigated	2,850	2,846	2,739	2,486	48.0%	47.9%	46.1%	41.8%
	Irrigated	1,895	1,816	1,975	2,176	31.9%	30.6%	33.2%	36.6%
	Totals	**4,745**	**4,662**	**4,714**	**4,662**	**79.8%**	**78.4%**	**79.3%**	**78.4%**
Channel									
	Channel	1,062	1,092	1,021	1,082	17.9%	18.4%	17.2%	18.2%
	Totals	**1,062**	**1,092**	**1,021**	**1,082**	**17.9%**	**18.4%**	**17.2%**	**18.2%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	5	0.0%	0.0%	0.0%	0.1%
	Totals	**0**	**0**	**0**	**5**	**0.0%**	**0.0%**	**0.0%**	**0.1%**
Transportation									
	Public Road	54	91	58	58	0.9%	1.5%	1.0%	1.0%
	Interstate	0	0	65	65	0.0%	0.0%	1.1%	1.1%
	Railroad	32	32	32	32	0.5%	0.5%	0.5%	0.5%
	Totals	**85**	**123**	**154**	**154**	**1.4%**	**2.1%**	**2.6%**	**2.6%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	137	177	1,212	0.0%	2.9%	3.7%	26.0%	2.9%	0.8%	22.3%	26.0%
	Flood	1,895	1,679	1,798	964	39.9%	36.0%	38.1%	20.7%	-3.9%	2.1%	-17.5%	-19.3%
	Totals	**1,895**	**1,816**	**1,975**	**2,176**	**39.9%**	**39.0%**	**41.9%**	**46.7%**	**-1.0%**	**2.9%**	**4.8%**	**6.7%**

Non-Irrigated

Multi-Use	2,758	2,449	2,400	2,138	58.1%	52.5%	50.9%	45.9%	-5.6%	-1.6%	-5.0%	-12.3%
Hay/Pasture	92	397	339	348	1.9%	8.5%	7.2%	7.5%	6.6%	-1.3%	0.3%	5.5%
Totals	**2,850**	**2,846**	**2,739**	**2,486**	**60.1%**	**61.0%**	**58.1%**	**53.3%**	**1.0%**	**-2.9%**	**-4.8%**	**-6.7%**

RIPARIAN

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

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

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.5	0.5	1.1	1.4	0.8	1.2	1.6	1.9	5.4
Max	33.2	155.4	177.4	229.3	28.0	77.6	137.1	47.9	47.1
Average	8.5	17.1	19.1	24.7	11.1	16.2	21.0	23.9	24.3
Sum	169.9	411.4	477.9	468.6	177.1	355.7	188.7	287.1	121.5

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	130.1
Channel to Riparian (acres)	248.3
Riparian Encroachment (acres)	**118.2**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	218.2
1950s Floodplain Mapped as 2011 Channel (Ac)	92.3
Total Recruitment (1950s to 2011)(Ac)	**310.6**

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	2.4	121.5	73.2	0.0	**197.1**
Acres/Valley Mile	0.5	25.8	15.5	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	104.53	2.59%	1.31	2.05	9.26	4.44

FISHERIES SUMMARY

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

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

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

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

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	304.8	179.4	17.6%
Rip Rap Margin	3.2	3.1	0.3%
Bluff Pool	46.4	45.5	4.5%
Secondary Channel	64.2	52.4	5.1%
Secondary Channel (Seasonal)	165.7	112.4	11.0%
Channel Crossover	133.1	100.8	9.9%
Point Bar		83.0	8.1%
Side Bar		45.6	4.5%
Mid-channel Bar		23.7	2.3%
Island	292.2	295.5	28.9%
Dry Channel		79.4	7.8%

AVIAN

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

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.