U.S. Army Corps of Engineers
Omaha District

Yellowstone River
Conservation District Council

Yellowstone River
Cumulative Effects Analysis

FINAL

December 2015

Suggested Citation:

U.S. Army Corps of Engineers and Yellowstone River Conservation District Council. 2015. Yellowstone River Cumulative Effects Analysis. U.S. Army Corps of Engineers Omaha District. Omaha, NE

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"Working relationships yield a shared vision…"

August 14, 2015

Dear Reader,

The Yellowstone River Conservation District Council (YRCDC) is a grassroots, locally led organization composed of eleven Conservation Districts along the Yellowstone River, working to complete the Cumulative Effects Analysis study (CEA) and develop voluntary management recommendations for the river and its riparian areas.

The Yellowstone River stretches over 680 miles and is the longest free-flowing river in the lower 48 states. The study covers the 565-mile reach of the river from Gardiner, Montana to its confluence with the Missouri River in North Dakota.

On May 20, 1999, six environmental organizations filed a lawsuit in US District Court in Billings, Montana, contending that the US Army Corps of Engineers (Corps) had doubled the number of bank stabilization permits on the Yellowstone River between 1995 and 1997 over the previous 12 years.

The complaint stated the Corps issued the permits without understanding the cumulative impacts of those projects on river health. The judge ruled against the Corps and a short time later the US Congress authorized the Corps to conduct the Yellowstone River Corridor Comprehensive Study to determine the cumulative hydrologic, biological, and socioeconomic impacts of human activity on the Yellowstone River.

In 2004, the YRCDC and the Corps entered into a cost-sharing agreement and agreed upon a scientific project study plan for what is known as the Cumulative Effects Analysis (CEA), which could provide the basis for the Yellowstone River recommended management practices on the river.

The YRCDC has remained committed to providing leadership, assistance, and guidance for the wise use and conservation of the Yellowstone River during this entire process, and strongly supports the scientific studies on which to base management recommendations. YRCDC's purpose is to provide local leadership, assistance, and guidance to sustain the system's natural resources and improve social, environmental and economic values along the river corridor.

In an effort to encourage broad-based local, regional, and national understanding and support for the CEA, the YRCDC has sponsored several demonstration projects, meetings, tours, and workshops. The YRCDC has been conducting a series of workshops for Conservation District supervisors, landowners, and other decision-makers to convey CEA conclusions and gather public input on draft voluntary river management recommendations.

YRCDC implements its purpose through the following fundamental precepts: 1) the need for sound scientific information on which to base management decisions; 2) the need for broad-based local, regional, and national input, to define a shared vision that will provide a foundation for resolving issues; 3) the need for technical and financial assistance to address sustainable use issues on the Yellowstone River; 4) the need to maintain constructive dialog with all users and stakeholders; 5) the need to educate and inform the public to help create a vision for the future of the river; and 6) the need to establish a baseline for future evaluation of trends based on scientific data.

The YRCDC has focused on the following points which are central to the Conservation Districts bordering the Yellowstone River and vital to all its stakeholders: 1) sound and accurate scientific information on which to base future decisions; 2) bank stabilization (310 issues); 3) irrigation water impacts, availability, and water reservations; 4) livestock, grazing, and farming issues; 5) water quality and stream impairment; 6) recreational uses of the river and the floodplain; 7) municipal and domestic water needs and impacts; 8) scenic and aesthetic values of the river corridor; and 9) fisheries and wildlife habitat stability.

The YRCDC acknowledges the importance of partnerships which have been developed since its inception. The study area is immense, with many diverse groups having interests in varied topics specific to certain portions of the river. This undertaking is truly a well-grounded grass roots effort with representation from every county along the river and many groups with a wide range of specific interests.

Early on it was agreed that our differences would be handled through constructive dialog, rather than angry opposition. From that point, relationships have grown and the YRCDC has been open to listening to all points of view on the river. These relationships not only include diverse groups, but many agencies (some of which are regulatory) and academics who have committed to the locally led effort.

When undertaking a study of this magnitude, it is necessary to understand the social relationships that determine how the efforts will be accepted. By having the Conservation Districts involved in each county, the effort takes on a local flavor with landowners being approached by other landowners and people in their community. The feedback was honest and straightforward making the acceptance of the end product, voluntary management practices, a more realistic goal. Without the cooperation of the landowners, very little could be accomplished as 80% of the lands bordering the Yellowstone River are privately owned.

We are proud to present this Cumulative Effects Analysis document to all who appreciate and value the Yellowstone River. The commitment of the members of the Council and our partners has produced a one of a kind scientific research document that will be read and used by countless people in the years to come. We hope all who use this research tool will understand the passion and devotion of all who were involved with producing this invaluable analysis assessment.

Sincerely,

Don Youngbauer, Chairman

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ACRONYMS/ABBREVIATIONS

Acronym/Abbreviation	Definition
7Q10	The lowest 7-day average flow expected to occur every 10 years
AFO	Animal feeding operation
AgInf	Areas of agricultural infrastructure
AUID	Assessment unity identification code
BMPs	Best Management Practices
CAFO	Concentrated animal feeding operation
CEA	Cumulative Effects Analysis
cfs	Cubic feet per second
CM	Confined meandering (channel type)
CMZ	Channel Migration Zone
Corps	U.S. Army Corps of Engineers
CS	Confined straight (channel type)
CWA	Clean Water Act
DNRC	Montana Department of Natural Resources and Conservation
DO	Dissolved oxygen
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
HUC8	8-digit hydrologic unit
LiDAR	Light Detection and Ranging
LWD	Large woody debris
MDEQ	Montana Department of Environmental Quality
MFWP	Montana Fish, Wildlife & Parks
MPDES	Montana Pollutant Discharge Elimination System
NAWQA	National water quality assessment program
NRCS	National Resources Conservation Service
NRIS	Montana Natural Resource Information System
NWI	National Wetland Inventory
PAH	Polynuclear aromatic hydrocarbon or polycyclic aromatic hydrocarbons
PCA	Partially confined anabranching (channel type)
PCB	Partially confined braided (channel type)
PCM	Partially confined meandering (channel type)
PCM/I	Partially confined meandering/islands (channel type)
PCS	Partially confined straight (channel type)

Acronym/Abbreviation	Definition
PSOC	Potential species of concern
PWS	Public water supply
RMA	Restricted Migration Area
SOC	Species of concern
SPARROW	Spatially Referenced Regression on Watershed Attributes (USGS)
SSCV	Shallow, slow current velocity
SVOC	Semi-volatile organic compound
T&Y	Tongue & Yellowstone Irrigation District
TDS	Total dissolved solids
TMDL	Total maximum daily load
UA	Unconfined anabranching (channel type)
UB	Unconfined braided (channel type)
USBOR	Bureau of Reclamation
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
US/I	Unconfined straight/islands (channel type)
USGS	U.S. Geological Survey
VOC	Volatile organic compound
WMA	Wildlife Management Areas
WWTP	Wastewater treatment plant
YRCDC	Yellowstone River Conservation District Council
YRRP	Yellowstone River Recommended Practice

GLOSSARY

100-Year Inundation Boundary – Area frequently analyzed in this study that may be inundated in the 1% frequency flood (or 100-year flood). Based on a GIS inundation model, not a hydraulic modeling system. Assumes no levees, roads, or other obstructions present that may currently block flows from the floodplain.

Acre-foot – The volume of water that will cover one acre of surface area to a depth of one foot. One acre foot is equivalent to approximately 326,000 gallons.

Alluvial – Relating to unconsolidated sediments and other materials that have been transported, deposited, reworked, or modified by flowing water.

Anabranching – A section of river or stream channel with more than one channel separated by vegetated or semi-vegetated islands.

Avulsion - A sudden cutting off or separation of land by a flood or by abrupt change in the course of a stream, as by a stream breaking through a meander or by a sudden change in channel location whereby the stream deserts its old channel for a new one. The result is often the formation of a straighter channel pattern characterized by an increase in channel bed slope and decrease in channel length.

Bankfull Depth - Refers to the maximum depth of flow measured from the channel low-point (thalweg) to the estimated bankfull elevation.

Bankfull Discharge - The discharge corresponding to the stage at which flow is contained within the limits of the river channel, and does not spill out onto the floodplain. The stage just before over bank flow begins.

Channel Migration – The process of a river or stream moving laterally (side to side) within its floodplain. This process can be slow or fast and the rate is usually affected by the type of soils present in the banks, land use, the volume of water and its power to erode the banks.

Channel Migration Zone – The floodplain area subject to natural channel migration. For this study, the collective area where the river has meandered since 1950.

Consumptive Use – Use of surface or groundwater in the study area that is not directly returned to the river. For example, domestic water is used in households and then sent to septic systems or wastewater treatment plants that may discharge to groundwater or surface water after a period of days, weeks, or months, but reduces water levels at the point of diversion.

Evapotranspiration – The sum of the processes that turn water into water vapor from evaporation of water from soil and waterbodies plus transpiration of water through plants that take up water and then release it through their leaves.

Exurban – Low density development of houses on 5 to 40 acre lots.

Flood frequency – The statistical probability that a flood of a certain magnitude for a given river will occur in a certain period of time.

Floodplain- Flat or nearly flat land adjacent to a stream or river that stretches from the banks of its channel to the base of the enclosing valley walls and experiences flooding during periods of high discharge.

Fluvial - Formed or produced by the action of flowing water; of, pertaining to, or inhabiting a river or stream.

Geomorphology - The study of landscape evolution including shape, form and process through space and over time. It is the earth science that focuses on understanding the processes of erosion, weathering, transport, and deposition, with measuring the rates at which such processes operate, and with quantitative analysis of the forms of the ground surface and the materials of which they are composed.

GIS – Geographic Information Systems: A system of hardware and software used for storage, retrieval, mapping, and analysis of geographic data.

Heterogeneity – Comprised of a mix of properties. In the context of habitat, a mix of many different types of habitats or plant communities.

Hydrology – The study of properties, movement, distribution, and effects of water on the Earth's surface.

Hydraulics – The study of the physical and mechanical properties of flowing liquids (primarily water). This includes elements such as the depth, velocity, and erosive power of moving water.

Large Woody Debris (LWD) - Functional wood in streams is called *large woody debris*. The definition of large woody debris varies. However, for the purposes of this study, the typical size of LWD are 18-36 inches in diameter and 12 – 32 feet in length.

Meander - One of a series of regular freely developing sinuous curves, bends, loops, turns, or windings in the course of a stream.

Morphology - Of or pertaining to shape.

NAIP – National Agriculture Imagery Program: A United States Department of Agriculture program that acquires aerial imagery during the agricultural growing seasons in the continental U.S.

Periphyton - Aquatic organisms, such as certain algae, that live attached to rocks or other surfaces.

Planform - The configuration of a river channel system as viewed from above.

Prograding - The advancing or growth of a bar deposit**.**

Reach – Divisions within the larger geomorphic regions of the study area to facilitate the cumulative effects analysis. Reaches were delineated based on river form/pattern and the level of confinement and are shorter than 20 miles in length.

Return Interval- The likely time interval between floods of a given magnitude.

Riparian: Relating to or inhabiting the banks of a natural course of water. Riparian zones are ecologically diverse and contribute to the health of other aquatic ecosystems by filtering out pollutants and preventing erosion.

Riprap – Rocks placed to stabilize banks and provide other types of protection, such as from erosion.

River Corridor – The area of focus for this cumulative effects analysis comprising the mainstem Yellowstone River from Gardiner to the confluence with the Missouri River and the associated floodplain and surrounding area within the twelve counties that the river flows through.

Seral-stage - Of or pertaining to plant succession and its relation to disturbance mechanisms such as floods or fires over time. A particular plant community type or dominant species may represent a *seral*-stage along a temporal scale.

Segment – Study zones for the socioeconomic analyses conducted for this study, delineated based upon similar economic characteristics. The segments are not delineated in the same location as the study reaches.

Sinuosity - The measurement of a channel's relative straightness or curving configuration. It is the ratio of channel length to downward valley length; for example, a value of one 1.0 is a straight channel pattern, whereas a sinuosity of 1.5 is considered meandering.

Sparrow – The USGS SPARROW (Spatially Referenced Regression on Watershed Attributes) surface water quality model is used to estimate nitrogen and phosphorous yields and quantify the importance of various nutrient sources. The model uses calibrated models to predict long-term average loads, concentrations, yields, and source contributions for all stream reaches (monitored and unmonitored) within the modeled watersheds.

Stream competency - The ability of a stream to mobilize its sediment load; refers to the maximum size of particles of a given specific gravity; which, at a given velocity, the stream will move.

Stream power - The rate of energy dissipation against the bed and banks of a stream per unit downstream length. It describes the potential for flowing water to perform geomorphic work, and is expressed as the product of water density, acceleration due to gravity, discharge, and channel slope.

Terrace - A step-like surface, bordering a valley floor or shoreline that represents the former position of a floodplain, or lake or sea shore. Practically, terraces are considered to be generally flat alluvial areas above the 100 year flood stage.

Wetland – Areas that possess unique types of vegetation and soils resulting from their frequent inundation or saturation by water.

Palustrine Wetlands – Wetlands not directly associated by surface or groundwater flow with a river, lake, estuary, or ocean.

Riverine Wetlands – Wetlands directly associated by surface or groundwater flow with a river or stream.

Watershed – An area of land where all of the groundwater and surface water drain down to the same outlet. Watersheds are typically separated by high ground such as ridges or mountain ranges.

Water Withdrawals – Direct withdrawal or diversion of surface or groundwater that may be used consumptively or may be returned to the river or groundwater near the point of diversion or downstream.

Wetland Vegetation Types – Different plant communities occur in wetlands depending on the depth and duration that water is present. Emergent wetlands are dominated by grasses and other non-woody plants; scrub or shrub wetlands are dominated by woody shrubs or saplings such as willows; forested wetlands are dominated by trees such as cottonwoods.

EXECUTIVE SUMMARY

This report presents the results of the Cumulative Effects Analysis (CEA) conducted for the Yellowstone River Corridor Study. The corridor study was led jointly by the Yellowstone River Conservation District Council and the U.S. Army Corps of Engineers, with participation from multiple federal, state and local agencies as well as several non-profit organizations and private businesses. It has been undertaken as a result of public attention and concerns about the combined effects of damaging flood events (1996 and 1997) and increased development pressures along the Yellowstone River Corridor. The study focuses on the 12 counties along the mainstem river corridor from Yellowstone National Park to the confluence with the Missouri River in North Dakota (see Figure ES-1).

“Cumulative effects” refers to the sum of incremental effects from a variety of human activities that collectively alter an ecosystem. While the effects from a single activity may be small, a combination of similar activities and their associated effects can significantly degrade natural resources, particularly over a period of time. On the Yellowstone River, the cumulative result of 150 years of settlement and economic expansion has changed many aspects of the river and its floodplain.

The cumulative hydraulic, biological, and socioeconomic impacts of human activity on the Yellowstone River have been evaluated using data collected during the course of this study as well as from other sources. The analysis includes an interdisciplinary scientific characterization of relationships between human activities and the resulting river system response. This cause and effect analysis has been completed for a series of individual river elements and is based on current knowledge regarding human influences and river response trends. The analysis provides a basis for recommended management practices that are intended to reverse or slow further degradation of the river’s ecosystem while supporting traditional land uses and economic livelihoods. The set of Yellowstone River Recommended Practices (YRRPs) have been developed to help residents along the river corridor maintain both the economy of the region and the long-term biological and physical integrity of the Yellowstone River. Citations and academic references are provided within the CEA chapters.

Background

The Yellowstone River watershed consists of about 71,000 square miles of land in Wyoming, Montana, and North Dakota (Figure ES-1). The watershed is strikingly asymmetric, with the vast majority of the watershed area on the south side of the Yellowstone River. Its main tributaries, all of which enter the river from the south, include the Boulder, Stillwater, Clarks Fork Yellowstone, Bighorn, Powder, and Tongue Rivers. The subwatersheds of the Yellowstone basin range from the volcanic plateau of Yellowstone National Park to the granitic Wind River Range of west-central Wyoming and badlands areas of eastern Montana and Wyoming. The watershed fully encompasses several major mountain ranges such as the Absaroka Range, Beartooth Mountains, Bighorn Mountains, and Pryor Mountains.

As a national resource, the Yellowstone River itself is without parallel. The river originates in the nation’s first national park, and it is commonly referred to as the longest free-flowing river in the lower 48 United States, as there are no major dams or reservoirs on the mainstem. It is nestled within the largest relatively intact temperate zone ecosystem on the planet, the Greater Yellowstone.

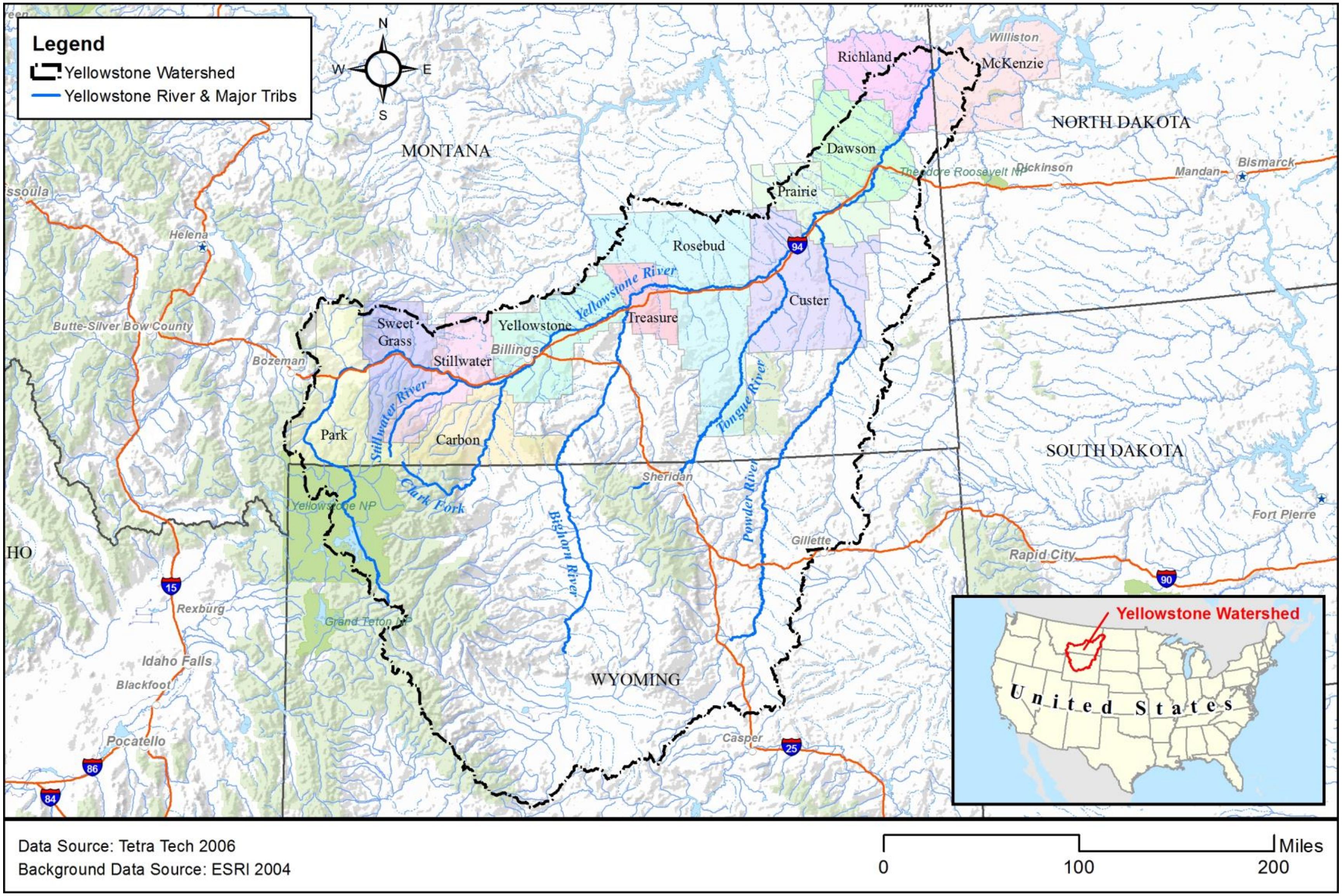

Figure ES-1 Yellowstone River Watershed, showing counties within Montana and major tributaries

Between Gardiner, Montana and the Yellowstone River/Missouri River confluence in North Dakota, the physiography of the Yellowstone River and its tributaries transitions from steep, confined mountainous areas to plains conditions. This physiographic transition correlates to a shift in the natural hydrology of the system as it changes from a predominantly snowmelt-driven hydrology in the upper reaches to a combined mountain snowmelt/prairie runoff hydrology further downstream. The river also transitions from a coldwater salmonid-dominated fishery in the upper reaches to a warmwater fishery in the lower reaches. The watershed supports over 200 plant and animal species of conservation concern.

The Yellowstone River Corridor is culturally and historically significant, having a long history of Native American occupation followed by distinct periods of fur trapping, steamboat navigation, railroad development, and agricultural expansion. The Crow tribe originally called the river Ikchiilkaashaashe, or "Elk River". Later, French fur trappers named the river La Roche Jaune, or "Yellow Rock". The name "Yellowstone River" stems from the Minnataree Indians (a branch of the Siouan Hidatsas), who called the river Mi tse a-da-zi, or Yellow Rock River. In 1805, when the Lewis and Clark expedition came into contact with the Minnataree, they adopted the name Yellowstone River. Historians differ on the geographic source of the term "yellow stone", but based on the range of the Minnataree, it is generally accepted that the name stems from the sandstone cliffs that closely follow much of the lower river rather than the yellow thermally-altered rock formations in what is now Yellowstone National Park.

While the Yellowstone River remains geomorphically and biologically diverse, cumulative human influences over the past 150 years have resulted in a less dynamic and less complex river relative to historic conditions. The nature and magnitude of the river's responses to human influences vary substantially by location. In the upper river, bank armoring is a prominent driver of change, whereas the lower river is most significantly impacted by shifts in flow patterns primarily caused by tributary reservoirs. Physical constraints imposed by levees, dikes, roads, and railroads extend throughout the system. The influences of urban/exurban development are localized within the few major communities along the river. Other impacts such as climatic trends may also be altering the entirety of the river system, although these impacts and responses are difficult to assess.

Study Area

The primary study area extends along the mainstem of the Yellowstone River from Gardiner, Montana, at the northern boundary of Yellowstone National Park, to its confluence with the Missouri River in McKenzie County, North Dakota, a distance of 565 river miles (as measured in 2001). The analysis focuses on the river and its approximately 200,000 acre floodplain. The study area is almost entirely within the state of Montana, with the lowermost 15 miles in western North Dakota. Although the study focuses on the river and its floodplain, several of the analyses such as hydrology and water quality extend across the entire watershed due to their collective influence on the mainstem.

Although the primary Yellowstone River study area extends from Gardiner, Montana to the mouth, there are several data gaps in Park County. Cumulative effects in Park County, which is located in the upstream-most portion of the river corridor, were addressed in previous work by the Governor's Task Force between 1997 and 2003 in response to flood events in 1996 and 1997. As a result, data collected for this CEA were not necessarily collected for that area. Some datasets that were available from the Governor's Task Force effort were used in this analysis, including physical features mapping and digitized banklines. Other Park County datasets collected as part of this effort include hydrologic analyses, land use mapping, channel migration rate measurements, and Channel Migration Zone mapping. The datasets that are most notably missing are hydraulic analyses of floodplain connectivity, floodplain turnover rate measurements and riparian mapping.

The general starting point for the Cumulative Effects Analysis is 1950. Most of the analysis of change through time begins at that point, which marks the earliest comprehensive set of aerial imagery for the river corridor. Where possible, changes that occurred in the river system prior to 1950 are discussed and quantified.

Primary Yellowstone River System Human Influenced Changes

The following section summarizes the primary human influences and changes that have been evaluated and integrated to assess cumulative effects. These include hydrologic changes, geomorphic changes, shifts in riparian conditions, and additional human influences on water quality, wildlife habitat (avian), invasive species, and fisheries.

Altered Hydrology

The alteration of the natural hydrology of the Yellowstone River system has had a large effect on the Yellowstone River and its floodplain. Most notably, reservoirs in the Bighorn River watershed, a major tributary watershed to the Yellowstone River, have exerted a major influence on the hydrology of the lower Yellowstone. Additionally, irrigation-related water use on the Yellowstone River mainstem and other tributaries (primarily the Clarks Fork) has also contributed to changes in flows on the river. The primary findings from the analysis of Yellowstone River hydrology indicates the following:

Gardiner to the mouth of the Clarks Fork River: Primary hydrologic changes are related to irrigation, which shows an increasing influence of irrigation withdrawals in the downstream direction. At Gardiner, very little influence is observed, although some research indicates that climatic shifts have resulted in a 25 percent reduction in mean August flows since 1950, and that this reduction is demonstrably linked to climatic variables. At Livingston, the effects of irrigation on the overall flow regime are imperceptible, but by the mouth of the Clarks Fork, the results indicate an approximate 23 percent reduction in the summer low flows (the 7Q10, which is the lowest 7-day flow expected to occur every 10 years during summer months). This may in part relate to the climatic shifts described above. The 2-year flood, which has a strong influence on channel development, has dropped by 1,600 cfs or 5 percent with human development by the Clarks Fork. Larger floods are minimally affected.

Mouth of Clarks Fork River (Laurel) to the mouth of the Bighorn River (Bighorn): From the Clarks Fork to the Bighorn River confluence (Laurel to Bighorn), the influences of irrigation on Yellowstone River hydrology become more pronounced, indicating a measureable effect from irrigation in the Clarks Fork basin. Just below the mouth of the Clarks Fork River, the changes in flow statistics due to human influences include a 3,900 cfs or 7 percent drop in the 5-year flood flow, and a 4,200 cfs or 10 percent drop in the 2-year flood flow. At the Billings gage, summer baseflows are estimated to have dropped by 1,620 cfs or about 40 percent.

Mouth of Bighorn River to Missouri River confluence: The most pronounced hydrologic changes on the Yellowstone River have occurred below the mouth of the Bighorn River. The Bighorn Basin has seen major changes in water delivery to the Yellowstone River due primarily to the impacts of multiple reservoirs. The largest, most-downstream impact on the Bighorn River is Yellowtail Dam and Bighorn Reservoir, located about 96 valley miles upstream of the Yellowstone River confluence at Bighorn.

Immediately below the mouth of the Bighorn River, the 100-year flood magnitude on the Yellowstone River has dropped by 19,100 cfs or 16 percent. The 10-year flood has been reduced by 16,200 cfs or 19 percent, and the 2-year flood has dropped by 13,700 cfs or 23 percent. Downstream, these major reductions in flood magnitudes have reduced the lateral extent of flooding, frequency and duration of side channel inundation, and overall channel size.

Water management in the Bighorn River Basin has also contributed to the reduction in summer flows on the Yellowstone. At the Forsyth gage, for example, about half of the reduction in mean August flows can be attributed to Bighorn River flow alterations; the rest is attributable largely to irrigation.

Flow alterations on the Bighorn River have also affected fall and winter flows on the Yellowstone. Fall and winter low flows have increased by about 60 percent mainly due to flow release patterns at Yellowtail Dam.

Bank Armoring

Bank armoring is a common practice on the Yellowstone River because bank erosion rates locally exceed tens of feet per year, threatening valuable lands and infrastructure. As bank armoring has a cumulative impact on river process, it is a major component of the cumulative effects analysis. As of 2011, there were approximately 136 miles of bank armor on the Yellowstone River below Gardiner, including rock riprap, flow deflectors, concrete riprap, car bodies, and minor extents of other techniques such as gabions and steel retaining walls. Rock riprap constitutes about 75 percent of the total armor.

When summarized by county, mapped physical features data indicate that Yellowstone and Park Counties host the greatest extent of bank armor on the Yellowstone River; collectively these two counties contain almost one half of all of the mapped bank protection. When normalized to channel length, however, the density of armor in these two counties is only moderately higher than other counties in the upper river. The most intensive bank armoring is over the 320 river miles between the Paradise Valley (upstream of Livingston) and Miles City. Over this river length, there are about 120 miles of armored bank, which amounts to 18 percent of the river bank being armored. Below Miles City, about 4 percent of the total bankline is armored.

The main land uses that are protected by bank armor are agriculture and the active rail line, which collectively account for 73 percent of the total armor. The third most common use of bank armor is in urban/exurban areas. In river reaches that include Livingston, Columbus, and Billings, for example, about 30 percent of the total river bankline is armored, and locally, armoring density can be much higher.

Between 2001 and 2011, about 13 miles of armor were constructed on the river, reflecting a 10 percent expansion of total armor length during that decade. The most rapid rate of armor expansion occurred between the Paradise Valley and Billings. In contrast to new armor being constructed during that time, existing bank armor failed in numerous places. At least four miles of bank protection failed during that decade, and much of that failure reportedly occurred during the 2011 flood. Failure typically consisted of armor flanking and accelerated erosion behind the flanked armor, such that the armor remnants are often left sitting out in the river. Almost all of the failed armor were flow deflectors and concrete rubble around Billings and downstream from Forsyth.

Floodplain Isolation

Floodplains are those areas adjacent to rivers that are prone to periodic flooding. Floodplains can be considered in terms of their typical expected probability and magnitude of flooding in any given year. For example, the 100-year floodplain, which has a 1% chance of being flooded in any given year, has a much higher flow and the associated floodplain is much larger than a 5-year floodplain, which has a 20% chance of being inundated in any given year. One aspect of the CEA is the evaluation of the loss of connectivity between the Yellowstone River and its historic floodplain. The 100-year floodplain, although rarely flooded, provides important functions with regard to flood storage and soils development, and the 5-year floodplain, reflects near channel areas that support more typical riparian habitats such as cottonwood forest. The isolation of each of these respective floodplain areas has been quantified for the CEA. Floodplain isolation was determined via modeling of undeveloped flow conditions on an undeveloped floodplain, and comparing those results to the modern, developed flow condition and developed floodplain.

Results of the CEA indicate that between the Park/Sweet Grass County line (Springdale) and the mouth of the Yellowstone River, over 21,000 acres of the historic 100-year floodplain has become isolated due to physical encroachments, land grading, and hydrologic alterations. The primary cause of floodplain isolation is the reduction in peak flows described above. Reductions in the 100-year flood magnitude below the mouth of the Bighorn River have resulted in the isolation of over 8,000 acres of the 100-year floodplain. The other primary causes are agricultural infrastructure and the active railroad line, which have isolated 3,720 and 3,526 acres, respectively.

The individual causes of floodplain isolation are generally concentrated in certain portions of the river corridor. For example, transportation-related isolation is almost entirely occurring in the vicinity of Billings. Agricultural-related isolation is most common near Hysham and upstream of Miles City. Loss of floodplain due to the reduction in high flows is most pronounced where the river floodplain is especially broad, including the Mission and Hammond Valleys between Hysham and Forsyth and from Sidney to the Missouri River confluence. Urban levees contribute to minor additional isolation of the floodplain, primarily at Forsyth, Miles City, and Glendive.

The changes in flow conditions and construction of floodplain features have also resulted in the isolation of more frequently inundated, geomorphically important floodplain areas. In total, almost 30,000 acres or 23 percent of the historic 5-year floodplain area has become isolated on the Yellowstone River below Springdale. The majority of floodplain isolation is due to flow alterations on the Bighorn River. Whereas about 9 percent of the 5-year floodplain upstream of the Bighorn River confluence is isolated, almost 30 percent is isolated below the confluence. Mapped inundation for the 2-year floodplain shows similar results, and the consequences include both less floodplain coverage and reduced flows in side channels.

Although modeling results were not available for Park County, long extents of floodplain dikes and levees indicate that floodplain isolation has been extensive in that area as well, which includes the Paradise Valley and the city of Livingston.

Side Channel Isolation

Side channels on the Yellowstone are fairly ubiquitous, forming long channels around forested islands that can be several miles long. These channels flow year-round, and are very diverse in terms of their size, length, and proximity to the main river channel. Side channels on the Yellowstone River have been recognized as important fish habitat throughout the river system, such that the intentional diking and isolation of these channels may have a significant impact on river ecology.

Results of the CEA indicate that in 1950, there were 508 miles of active side channels on the Yellowstone River. By 2001, that length had been reduced to about 463 miles, reflecting a net loss of approximately 45 miles during those 51 years. Although side channel lengths naturally fluctuate with time, physical features mapping indicates that from 1950 to 2001, about 47 miles of side channels were blocked by constructed dikes. Further analysis showed that prior to 1950, another 42 miles had already been blocked. This indicates a total loss of about 89 miles of side channels due to intentional blockages, most of which are very small features built to improve access to agricultural ground.

Development in the Channel Migration Zone

The Channel Migration Zone (CMZ) is the river corridor footprint that, based on historic rates of channel movement, would accommodate 100-years of natural channel migration. Development within the CMZ is therefore a likely driver of channel and floodplain manipulation. The entire CMZ footprint on the

Yellowstone River is about 64,000 acres. About 24,000 acres or 38 percent of that area has been developed for either urban/exurban, transportation or irrigated agricultural land uses. The majority of the development within the CMZ has been to support irrigation, with approximately 20,400 acres or 32 percent of the CMZ in an irrigated land use category.

Riparian Conversions

Cottonwood forests are a dominant characteristic of the Yellowstone River corridor. Riparian environments along the river include these forests as well as riparian shrubs and non-woody riparian environments such as grassy meadows. These areas are a key component of all terrestrial habitat in the river environment, and the alteration of these habitats is a fundamental component of the CEA.

The extent, successional stage, and locations of riparian vegetation in the Yellowstone River corridor have changed from 1950 to 2011. It is important to note that the 1950 baseline does not represent pristine conditions. Historic accounts indicate that much of the extensive cottonwood forest reported by early day explorers along the Yellowstone River no longer exists, having been harvested or cleared and converted to other land uses prior to 1950.

Although the total corridor-wide extent of riparian vegetation has remained relatively consistent since 1950, there have been substantial local shifts in the patterns and extents of that vegetation. Over 6,800 acres of woody riparian vegetation that was present in the 1050s was converted to another land use by 2001. Most of this conversion was to irrigated agriculture. Riparian clearing in cities and towns accounts for over 1,100 acres of riparian conversion, and the Billings area accounts for 54 percent of that total change.

Below the mouth of the Bighorn River, the loss in riparian cover between 1950 and 2011 (6,858 acres) was offset by the encroachment of riparian vegetation into abandoned or blocked side channels.

Floodplain isolation has resulted in the separation of about 20,000 acres of riparian vegetation from active flooding during a 100-year event, and about 20 percent of that acreage is cottonwood forest. Most floodplain isolation is related to agricultural land uses (56 percent of total) or to railroad embankments (33 percent of total).

Wetlands

Riverine wetlands are those wetland areas directly associated with a river channel (in the river environment and flooded permanently to semi-permanently), whereas palustrine wetlands include both natural and created marshes, swamps, ponds, and bogs. There is no comprehensive historic wetland mapping for the corridor, so quantifying amounts of wetland area change for the study is not possible. However, wetlands have been mapped under the National Wetland Inventory (NWI) program, and their results have been summarized for the area. NWI mapped wetlands total about 15,000 acres in the corridor, with the highest wetland densities in the upper portions of the river, above Laurel (up to 140 acres per valley mile). The vast majority of wetlands are palustrine emergent wetlands, with only about 10 percent of the mapped wetlands being classified as riverine. One study that evaluated historic trends in two reaches on the Yellowstone estimated that between 1950 and 2001, there was an average loss of 8 percent of total wetland area. It was noted that the construction of artificial freshwater ponds over the last 60 years masks the actual extent of wetland losses.

Invasive Plant Species

Invasive plant species have been introduced to the river corridor both deliberately (pasture grasses and ornamental shrubs) and unintentionally via birds and wildlife or seed drift from other areas. Of most concern for the Yellowstone River corridor are Russian olive and saltcedar. Both Russian olive and saltcedar have substantial effects on native riparian plant communities and can cause geomorphic changes to the river through their dense growth on banks, bars, and islands.

Russian olive occupies about 4,600 acres of the 100-year floodplain. Its mapped extent expands in a downstream direction, with an abrupt increase near the mouth of the Clarks Fork River. Russian olive infestations appear to be especially aggressive in abandoned channels and on islands. About half of the total mapped Russian olive in the Yellowstone River corridor is located between the mouths of the Bighorn and Powder Rivers, where the broad floodplain and extensive abandoned channels provide ideal sites for invasive species. In this region, over 10 percent of the 1950s island areas and river channel has become colonized by Russian olive. No basin-wide systemic mapping has been completed for saltcedar, however it is recognized as a major concern, equal to or exceeding that of Russian olive.

Other invasive plant species listed as noxious weeds by the State of Montana occur in the study area, including spotted knapweed, Russian knapweed, leafy spurge, hounds tongue, and Canada thistle. These species are rapidly degrading native riparian communities and infesting riparian pastures. Common buckthorn is an example of a new invasive that is causing concern, but is not listed as noxious at this time.

Water Quality

The water quality parameters described in this report include hydrogen ion concentrations, dissolved oxygen, total dissolved solids, nutrients, trace elements, pesticides, hydrocarbons, water temperature, and suspended sediment. Biological data are discussed with respect to benthic algae, filamentous algae, macroinvertebrates and fish. Results indicate that the Yellowstone River is generally considered alkaline with a pH ranging from 7.4 to 8.6, and pH values generally increase in a downstream direction. Dissolved Oxygen (DO), which is a measure of how much oxygen gas is dissolved in water, is typically measured at concentrations of around 8 to 10 mg/l. There have been several instances of low DO below Billings, which may relate to moderate levels of eutrophication.

Tributaries are a major source of the Yellowstone River nutrient load, although total nitrogen and phosphorous values during the growing season are generally within the numeric standards proposed by the Montana Department of Environmental Quality (MDEQ). Even so, nutrient enrichment has been identified on the river, and nuisance growth of filamentous algae occurs in segments of the Bighorn and Clarks Fork rivers.

Results of nutrient delivery modeling indicate that the estimated delivered aggregated yield of total nitrogen to the Gulf of Mexico from the Yellowstone River is about 12 kg/ km^2/yr compared to other Mississippi River tributaries that contribute up to an estimated 1,318 kg/ km^2/yr. The model predicts that the largest source of total nitrogen delivered aggregated yield in the Yellowstone River basin is the Shoshone River basin in Wyoming followed by the Upper Yellowstone area. Farm fertilizers constitute an estimated 41 percent of the delivered nitrogen.

Water temperature data is very limited on the Yellowstone River, however during several warm summers, low flow conditions prompted fishing restrictions in the upper Yellowstone River due to elevated water temperatures. There have also been anecdotal reports of water temperature-related fish kills and movements of warmwater species further upstream.

Measurements of benthic algae in 2000 indicated the highest algal biomass occurs in the middle segments of the Yellowstone River near Billings and Forsyth. Values were also high in the Clarks Fork and Bighorn River. Filamentous algae showed a similar pattern.

Physical and Biological River System Responses to Human Influences

One of the objectives of the CEA is to identify cause and effect relationships associated with human influences in the Yellowstone River Corridor. . The evaluation of cumulative effects on a natural system is challenging due to the inherent complexity of interrelated cause and effect relationships. Because of the vast project area and the myriad of activities on the river, only those influences that have been identified as having a major effect have been evaluated in detail. These influences include hydrologic changes, land use changes, and construction of physical features on streambanks and in floodplain areas. The physical and biological responses to these influences include channel adjustments to altered flows, altered rates of channel movement due to bank armor, isolated side channel habitat, isolated floodplain area, and direct habitat alterations due to land development in the river corridor. Each of these responses then has secondary responses that can be considered in terms of water quality, avian habitat, fisheries habitat, and a range of other components of the river system. The following sections describe the physical and biological responses of the river system to the major human activities described above.

Physical Responses to Human Influences

The overall form and rates of change on the Yellowstone River have been affected by many of the human influences described above. The effects can be seen in channel dimensions, channel migration rates, floodplain turnover rates, rates of sediment and wood inputs to the river, and the extent and nature of gravel bars.

The most prominent geomorphic response to flow alterations on the Bighorn River is the reduction in the size of the river downstream of the mouth of the Bighorn. From there to the confluence with the Missouri River, the bankfull channel area of the Yellowstone dropped by over 4,000 acres between 1950 and 2001, which is a reduction of 11 percent. Reduced channel-forming flows (those flows most responsible for determining channel dimensions) as well as the loss of side channels due to blockages have likely contributed to this reduction in overall channel size. The reduction in size of the active channel footprint has provided conditions for riparian vegetation encroachment at the expense of in-channel habitat.

Flow and sediment supply alterations on the Bighorn River have resulted in major shifts in gravel bar features on the lower Yellowstone River. Since 1950, the total extent of mid-channel bars has dropped by about 1,100 acres or 43 percent. This has been accompanied by a loss of about 40.2 miles of secondary channels (channels that flow around open gravel bars at low flow). Most of the loss in secondary channel length occurred between Hysham and Forsyth and below Glendive. There has been a net gain of bank-attached bars, indicating a conversion of gravel bars in the middle of the river to gravel bars that are adjacent to the riverbank at low flow.

The combined effects of flow alterations and bank armor have resulted in a reduction in floodplain turnover rates on the river. Turnover rates reflect the average annual exchange between the river and floodplain within a given channel segment. This exchange (erosion and deposition) is a critical aspect of riparian habitat formation and succession. Since the mid-1970s, between the Park/Sweet Grass county line and the Missouri River confluence (Park County data were not available), the mean annual rate of total floodplain erosion dropped from 435 acres per year to 331 acres per year, which is a reduction of 27 percent. Mean annual channel migration rates have dropped by over 20 percent in most reaches. One consequence of lower floodplain turnover rates is reduced recruitment of large woody debris; the post-1976 data show a reduction in the recruitment of closed timber area (area with over 25% overhead canopy) by about 50 acres per year.

Land use changes on streambanks have also affected channel migration rates and floodplain turnover. Over a 25-year period, the river eroded into hay land and irrigated cropland an average of 40 to 50 feet further than through multiple-use ground which includes riparian forest. Every region shows this fundamental trend of increased rates of migration through hay/pasture land and ground irrigated by sprinkler or flood.

Flooding has also affected the geomorphology of the river. For example, upstream of the Bighorn River confluence, the river has largely maintained its overall size since 1950, with the exception of an abrupt expansion between 1995 and 2001 (likely a response to the 1996 and 1997 floods). Between the Park/Sweet Grass County line and the mouth of the Clarks Fork River near Laurel, the bankfull channel area increased by almost 1,700 acres or 10 percent between 1995 and 2001 suggesting an influence of major upper river flooding in 1996 and 1997 on channel size.

Riparian Responses to Human Influences

Downstream of the Bighorn River confluence, the reduction in peak flows has caused the active channel footprint of the Yellowstone River to shrink, and this change has been accompanied by the expansion of riparian vegetation into the old channel areas. This has resulted in a net increase of riparian vegetation in the active channel area on the lower river. This riparian expansion has been balanced by losses due to floodplain clearing, resulting in no net change in overall riparian extent.

The observed riparian expansion in response to altered flows essentially reflects a singular response to those flow alterations rather than any long-term trend. Below the Powder River confluence, individual reaches gained an average of about 30 acres of forest since 1950. Most of that can be attributed to gains in closed timber cottonwood forest, with substantial losses of shrub coverage. This indicates that the forest extent has increased in the short-term, providing more extensive, later successional cottonwood forest habitat since 1950 due to the maturation of younger age stands. However, the loss of shrub and young cottonwood acreage indicates a decline in regeneration that could result in a long-term loss of forest within these reaches that have historically provided the greatest extent of cottonwood forest habitat in the corridor. In general, below the mouth of the Bighorn River, there has been a transition to older age classes of cottonwoods, accompanied by a loss in acreage of younger forest. This transition was also seen in Park County upstream of Springdale.

Riparian turnover rates are an important indicator of riparian succession and long-term health. The geomorphic analysis indicates that rates of floodplain turnover in the river corridor have been reduced due to bank armor and flow alterations. Bank armor, by stopping channel movement, reduces the rates of point bar growth, which in turn reduces area for riparian colonization. Armor also isolates existing riparian areas from active erosion and potential recruitment into the river. As part of the Channel Migration Zone (CMZ) mapping, areas that would normally be in the active migration zone of the river but have become isolated due to bank armoring or dikes were mapped as Restricted Migration Areas. An analysis of the cover types in these areas indicates that about 11,200 acres or 7 percent of the riparian area has been isolated from the active river corridor due to physical features. Most of the isolation (>70 percent) is due to rock riprap and flow deflectors, with lesser amounts due to dikes and road/railroad prisms.

Russian olive has colonized near-channel areas, abandoned side channels, ditches, canals, surface drains, abandoned agricultural fields, and general riparian areas. There are some implications that Russian olive and saltcedar can cause channel narrowing and further restrict channel migration, however it is unclear how active these processes are on the Yellowstone River.

Avian Response to Human Influences

Many avian species observed along the Yellowstone River are dependent upon large expanses of cottonwood forest. The reaches with the most extensive forest habitat occur largely in the lower river below the mouth of the Bighorn River. Many of these reaches gained forest acreage since 1950, but also experienced a loss in shrub acreage (young forest) during that time period (there was a 41 percent decline below the Powder River), suggesting reduced regeneration of cottonwood forest, and a potential future long-term loss of forest habitat.

Many avian species observed along the Yellowstone River are dependent upon riparian grassland. Since 1950, more acres of herbaceous land (approximately 10,000 acres within the floodplain) have been converted to higher intensity agriculture than any other riparian habitat type.

Residential and agricultural development provides foraging habitat for Brown-headed Cowbirds, which lay their eggs in the nests of other bird species, causing negative impacts to bird populations in riparian forest habitats. In 80 percent of the study area reaches, more than one half of the existing cottonwood forest is potentially affected by cowbird parasitism. Most of the cottonwood habitat with low risk of parasitism in 2001 was located below the Bighorn River confluence, where many bird species that are negatively impacted by cowbirds also occur. Consequently, this area of the river may currently provide important habitat for these species, particularly those of conservation concern, such as Ovenbirds and Black-and-white Warblers.

The loss of mid-channel bars and secondary channels surrounding bars in Regions C and D represent a decline in the extent of prime nesting and foraging habitat for federally endangered Least Terns.

Fisheries Response to Human Influences

The consequences of physical impacts as well as geomorphic and riparian responses on the Yellowstone River have the potential to greatly influence the diverse fish communities in the system. However, the data available for the fisheries study reflect current conditions rather than historic trends. As a result, in a fashion similar to the avian study, the consequences of human influences on the fishery must be inferred from a combined understanding of existing conditions, habitat requirements, and habitat preferences for various fish species.

Results of the CEA indicate that reduced discharge from the Bighorn River and other tributaries has likely altered the ecological suitability of native fish habitat in these tributaries as well as in the mainstem Yellowstone River. Altered hydrology has a number of potential effects on the fish community. For example, floodplain areas are important for the river’s food web and as habitat for fish, and isolation of those areas can therefore affect the fishery. Reduced side channel availability reduces important fish, amphibian, and reptile habitats. Altered flow patterns can disrupt cues for fish movements and reproduction. Diminished channel migration rates reduce Large Woody Debris (LWD) recruitment, which hinders the creation and maintenance of diverse in-channel habitats. Less bank erosion also reduces sediment delivery from the banks which may provide important habitat forming materials. The reduction in summer low flows may increase temperature, as well as the rates of predation, competition and disease transmission. Increased water temperatures may influence fish distributions. Increased fall and winter discharges may increase fish energy needs during the cold low-metabolism season, alter ice dynamics and jamming, and reduce the influence of the low-elevation snowmelt pulse as a fish movement or spawning cue. Reduced hydrograph rise and fall rates may disrupt or weaken hydrologic spawning cues.

Bank stabilization affects fish communities by increasing floodplain isolation, altering main channel habitats, and reducing the availability of diverse lateral habitats such as side channels and backwaters. Altered land use and conversion of floodplain areas to other uses such as irrigated agriculture, urban and exurban areas may increase pollution, alter urban stream hydrology, and reduce recruitment of LWD, which in turn may affect the fish community. Altered riparian vegetation and wetlands affect many natural functions of the river that are important to fish such as dissipating flood energy, trapping sediments, filtering nutrients and other pollutants, providing fish habitat, and contributing to the biological productivity of the aquatic ecosystem. Altered water quality on the Yellowstone River is generally moderate and the potential effects on the fish community are unknown. However, catastrophic events such as oil pipeline ruptures and associated oil spills have the potential for stronger impacts on the fish community.

Altered longitudinal connectivity on the Yellowstone River is caused by mainstem diversion dams. Although the degree of fragmentation of fish populations caused by these dams is not fully understood for all dams and fish species, these dams potentially affect the distribution of some fish species and reduce the viability of some fish populations. Six large irrigation diversion dams (Huntley, Waco-Custer, Rancher's Ditch, Yellowstone Ditch, Cartersville and Intake) have impacted fish passage and habitat connectivity along the mainstem Yellowstone River. Intake Diversion, which is the downstream-most structure on the river, is a major passage barrier that is currently the focus of efforts to provide passage for a range of fish species. The structure currently blocks passage by Pallid Sturgeon, Shovelnose Sturgeon, and Paddlefish under most flow conditions. Cartersville Diversion Dam appears to be a complete barrier to passage for Shovelnose Sturgeon.

Altered mainstem to tributary connectivity due to diversions, culverts, and other barriers affects the fish community because many fish species use both habitats at some point in their life histories. In addition to creating fish passage barriers, irrigation withdrawals result in the entrainment of fish into ditches and canals. Although fish screens have been constructed at Intake Dam and at the T&Y dam on the Tongue River, entrainment is anticipated to remain a considerable cause of fish mortality on the river.

Although introduced species are present, overall the Yellowstone River remains a stronghold of native fish diversity, with the highest number of native fish in Montana. There are 59 fish species total, of which 22 species (37 percent) are nonnative. In terms of abundance, however, most nonnative fish are rare. Exceptions are in the coldwater or salmonid zone of the river where introduced Rainbow and Brown Trout dominate the fishery, and have contributed to the decline of the native Yellowstone Cutthroat Trout. Although most introduced fish species are relatively rare in the middle and lower river, the effect of introduced predators such as Smallmouth Bass, Walleye, and Northern Pike has not been studied. American Bullfrogs are established in the river floodplain near Billings and have the potential to cause declines in native amphibians and reptiles. There is some concern that the altered hydrologic conditions on the Yellowstone River may favor these introduced species. Recreational fishing is an important cultural and economic activity on the Yellowstone River. Sport fish populations are monitored and managed for sustainability by Montana Fish, Wildlife & Parks.

Cumulative Effects by Region

When considering the cumulative effect of human influences on a large river system, it is critical to recognize that the ecological responses of the river to a range of physical drivers can overlap, and complex relationships can develop that intersect the socioeconomic, physical, and biological components of the system. As a result, it is challenging to assign singular cause and effect relationships to many of the physical and biological changes that have been documented on the Yellowstone River. The following section is a general discussion of the changes that have been documented in each region, with some consideration of cause and effect. A more detailed consideration of both quantified and inferred cause and effect relationships is described in Chapter 7 of this report.

The cumulative effects summary is presented in the following pages by region (Figure ES-2). The regional breaks are generally located at major tributaries; there are breaks at the Clarks Fork River (Region A/B boundary), Bighorn River (Regions B/C boundary) and Powder River (C/D boundary). Region PC in the upper basin was added to the study later, and its break with Region A occurs at the Park/Sweet Grass county line. The breaks between regions either fall on, or approximate county boundaries. Regions have been further subdivided into reaches, which are discussed in more detail throughout the report.

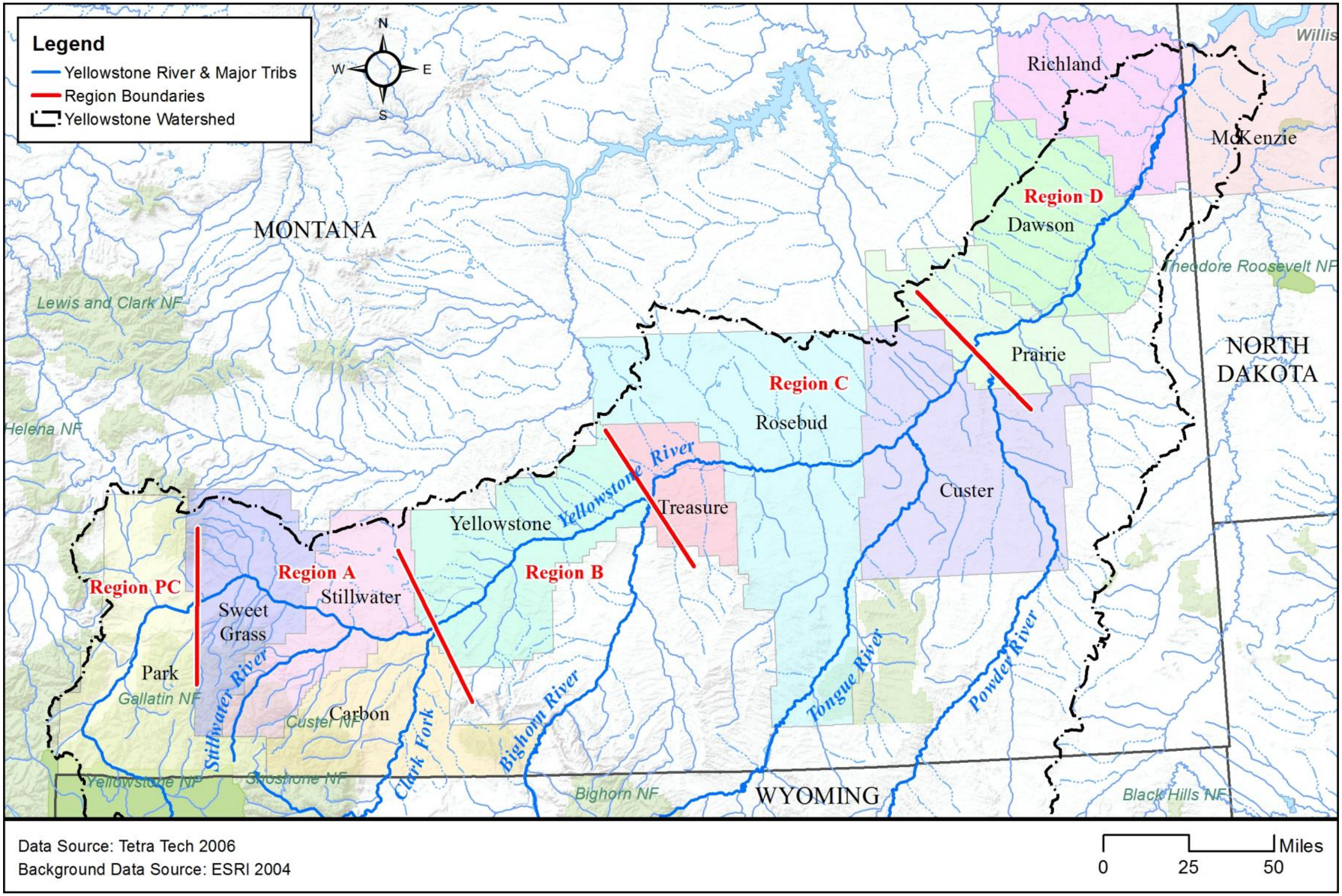

Figure ES-2 Region boundaries within the study area

Region PC: Park County

Region PC includes the entirety of Park County at the upper end of the study area, and includes 85 miles of the Yellowstone River. The population of Park County increased from about 12,000 people in 1950 to 15,636 people in 2011. The largest community in Park County is Livingston, which served as the Northern Pacific Railroad's repair and maintenance depot, at one point employing over 1,100 residents. The railroad has since declined as a major industry in town. More recently, recreation and tourism have begun to strongly influence the local economy. In 2011, four out of the top 10 industries in the county were related to recreation and tourism.

The cumulative effects observed in Park County relate primarily to land use changes both before and after the study baseline of 1950. Prior to 1950, the river corridor had been developed primarily for agricultural land uses and urban/exurban development in the vicinity of Livingston. Since then, historically rural areas of Park County have experienced substantial conversion from agricultural lands to urban/exurban land, much of which is rural residential development.

There has been substantial development within the Yellowstone River Channel Migration Zone (CMZ) in Park County. In total, about 24 percent of the natural CMZ has been developed, and the majority of that land is in urban/exurban land uses. Individual reaches in Park County show a relatively high level of CMZ restrictions by armor and dikes; in several reaches over 25 percent of the natural CMZ has been restricted.

Development within the CMZ in Park County is an important consideration with regard to cumulative effects, as it generally is associated with riparian clearing, floodplain isolation, and bank armoring. Although riparian mapping isn't available for Park County, the available data do indicate that bank armor and floodplain dikes are fairly ubiquitous in this region. In 2001, there were a total of 23.1 miles of armor in the region, and that had expanded to 30.7 miles of armor by 2011. As of 2011, about 18 percent of the bankline was armored, with the majority of that armor (26 miles) consisting of rock riprap. In several reaches over 25 percent of the bankline is armored. Between 2001 and 2011, at least 650 feet of rock riprap and 1,100 feet of flow deflectors were destroyed, primarily by flanking (erosion behind the revetments).

Extensive levees and dikes protect the community of Livingston, and also protect spring creek fisheries in the Paradise Valley. As of 2011, there were about 18.7 miles of dikes and levees mapped in the river corridor. This is the highest concentration of dikes in any region, with 0.22 miles of floodplain dike per river mile.

In Park County, side channels are probably important natural nursery areas for juvenile salmonids as they provide shallow, slow current velocity habitat when the main channel does not. Side channels are also important spawning areas for Yellowstone Cutthroat Trout, and a reduction in side channel habitat may be a factor in measured declines in cutthroat populations. There are at least nine side channels that have been blocked in Region PC. A total of 4.7 miles of side channels were blocked by floodplain dikes prior to 1950, and another 4.4 miles have been blocked since.

The hydrologic analyses presented in this report indicate that flood flow alterations due to human development in Park County have been minimal. The 100-year flood flow has been reduced by less than 1 percent due to human influences, and the 2-year discharge has dropped by about 2 percent in the lower end of the reach. These alterations are attributed largely to irrigation withdrawals during spring runoff.

Low flows have been impacted more substantially. At the Livingston Gage for example, summer baseflows have dropped by about 5 percent from 1,760 cfs to 1,680 cfs. These impacts relate to irrigation, consumptive water use, and climate variability. The total estimated water withdrawal in Park County in 2000 was 356 million gallons per day or almost 400,000 acre-feet per year. The vast majority of that use is for irrigation. The estimated consumptive use for irrigation is estimated to be about 66,000 acre-feet per year, which is about 362 cfs over a 3-month period. The estimated year 2000 consumptive use in Park County for public and other domestic water supply was 2.7 million gallons per day, or 3,033 acre-feet per year. There is also evidence that climatic shifts have resulted in a 25 percent reduction in mean August flows since 1950 at Gardiner.

Region A: Sweet Grass, Stillwater, Carbon Counties

Region A is 95 river miles long and extends from the eastern boundary of Park County at Springdale to the mouth of the Clarks Fork River, and includes the river corridor extent within Sweet Grass, Stillwater, and Carbon Counties. These three counties had a combined population of about 23,000 people in 2010. The economy is diverse, and includes mining, agriculture, and recreation. The economy of these three counties is currently changing, shifting from a primary focus on extractive natural resource activities, including mining and agriculture, to more recent expansion of recreation and tourism-based activities.

Similar to Region PC, the primary human influences in Region A are bank armor and to a lesser extent floodplain dikes, which have been driven by river corridor development. About 37 percent of the natural CMZ within Region A has been developed, with irrigation as the primary land use in the CMZ (2,919 acres or 32 percent of total CMZ). Since 1950, about 217 acres of riparian area have been cleared and converted to irrigation. There has also been major conversion of flood irrigated lands to pivot and sprinkler since 1950, indicating substantial investment in agricultural infrastructure.

These land use changes along with the proximity of the transportation corridor to the river have driven substantial bank armoring in the region, which is a primary contributor to the cumulative effects of human development in the region. As of 2011 there were 27.5 miles of bank armor in the region, protecting about 14 percent of the total bankline. Most of that armor (~23 miles) is rock riprap. The lower portions of Region A show the expanded use of concrete riprap relative to a predominance of rock riprap upstream.

About 13 miles of bank armor is protecting agricultural lands, and another 8 miles protects transportation infrastructure. In some areas, bank armor has dramatically narrowed the active river corridor to essentially the active channel width, causing major pinch points in the meander belt. Similarly, the bridge at Reed Point narrows the corridor to that of the bridge span. Between 2001 and 2011, at least 1,100 feet of rock riprap, 900 feet of concrete riprap, and 1,500 feet of flow deflectors were destroyed in Region A, primarily by flanking (erosion around and behind the revetments).

Region A has 2.3 miles of mapped floodplain dikes and levees, which at 0.02 miles of levee per river mile, is a relatively low concentration for the upper river.

Bank armoring has substantially reduced overall rates of channel movement and floodplain turnover in Region A, and as a result is a major component of observed cumulative effects. The mean migration rates measured in Region A dropped from 6.0 feet per year from 1950-1976 to 4.8 feet per year from 1976-2001. The rate of riparian forest erosion and LWD recruitment in Region A dropped by about 4 acres per year from 1950-1976 to 1976-2001.

Side channels have also been blocked in the region, which is another major contributor to the cumulative effects of human development. A total of 5.6 miles of side channels were blocked by floodplain dikes prior to 1950, and another 8.2 miles have been blocked since. In 1950, there were a total of 92.6 miles of side channel in Region A, and by 2001 that had been reduced to 75.3 miles, indicating some passive abandonment of side channels in addition to the blockages.

Between 1950 and 2001, Region A had an increase in total bankfull channel area of 1,210 acres or 17 percent. The majority of that channel expansion (870 acres) occurred between 1995 and 2001, and likely reflects the influences of the 1996 and1997 floods on channel size. Channel enlargement may also relate to disproportionate expansion of the main river thread with the loss of side channels.

Approximately 950 acres or 8.6 percent of the 100-year floodplain has become isolated in Region A, and most of that is due to the transportation corridor, including the active rail line (368 acres) and highways/roads (421 acres). Within this region, the railroad and frontage road closely follow the edge of the river corridor, causing most of the floodplain isolation. About 412 acres or 11 percent of the more frequently inundated 5-year floodplain in Region A has become isolated.

Region A has about 80 acres of cottonwood forest per valley mile, which is a relatively low value compared to downstream regions. Since 1950 there has been a loss of about 550 acres of forest considered to be at low risk of cowbird parasitism, which is a consequence of agricultural and urban/exurban development within and adjacent to riparian areas. This loss has reduced the extent of forest considered at low risk of cowbird parasitism by 45%. There are a total of 3,140 acres of mapped wetlands in the region, or a concentration of 36.4 acres of wetland per valley mile, which is the highest wetland density of any region. Some wetland areas have become isolated from the river by transportation infrastructure, mainly the active rail line on the south side of the river. There is a major expansion of Russian olive in the lower portion of Region A relative to upstream reaches.

High flow alterations in Region A have been minimal to moderate, with the changes increasing in the downstream direction. In the lowermost portions of the region just above the mouth of the Clarks Fork River, the 100-year flood flow has been reduced by about 2 percent, and the 2-year discharge has dropped by about 5 percent.

The summer 7Q10, which is the lowest 7-day flow expected to occur every 10 years during summer months, has been reduced by about 10 percent in the upper portion of Region A near Springdale, and by almost 30 percent at the lower end near Laurel. These changes are primarily attributable to irrigation and demonstrate how the influence of irrigation withdrawals on low flow increases in the downstream direction. The changes also potentially reflect climate variability.

Region B: Yellowstone County

Region B is 86 river miles long, from the mouth of the Clarks Fork River near Laurel to the mouth of the Bighorn River at Bighorn. It includes the majority of river corridor that lies within Yellowstone County, with the exception of the community of Laurel, which is just upstream of the mouth of the Clarks Fork River. Yellowstone County is known by the historical landmark Pompey's Pillar, as well as its cultural importance to the Crow Nation. The city of Billings is on the river and is the largest city in the state. Billings serves as an important economic center for Yellowstone County and the state of Montana. In 2010, over 10 percent of the total population of Montana was located in Billings. At that time, all of Yellowstone County had a population of 147,972 people.

The cumulative effects within the majority of Yellowstone County reflect the consequences of extensive river corridor development. This includes extensive CMZ development, riparian clearing, bank armoring, side channel blockages, floodplain isolation, and flow alterations. All of these impacts have cumulatively created a substantially altered river segment relative to historic conditions, with reduced rates of geomorphic change and highly altered aquatic and riparian habitats.

About 42 percent of the CMZ within Region B has been developed, with irrigation as the primary land use (3,406 acres or 32 percent of total CMZ). Almost 1,500 acres of land within the CMZ had been developed for urban/exurban and transportation land uses by 2011, which is the largest amount of such CMZ development in the entire study area. Of that area, 164 acres are in the Historic Migration Zone (HMZ), which is the area that was occupied by either stream channel or an island since 1950.

Since 1950, about 930 acres of riparian vegetation have been cleared in Region B for other land uses. This reflects an 8 percent reduction in the total extent of mapped riparian acreage. Most of that cleared area (618 acres) was converted to urban/exurban development. This clearing was concentrated around Billings; in one reach, 317 acres or 50 percent of the riparian vegetation was cleared, primarily for urban development. The development within Region B has substantially affected avian habitat. Since 1950 the forest extent considered at low risk of cowbird parasitism had dropped by 312 acres or 35%.

Development in the river corridor in Region B has resulted in extensive bank armoring, especially around Billings. As of 2011 there were 27.5 miles of bank armor in Region B, protecting about 14 percent of the total bankline. Most of that armor (~23 miles) is rock riprap. Region B also has 9 miles of mapped floodplain dikes and levees. In the vicinity of Billings, one 15.4 mile long reach has 11 miles of bank armor.

Between 2001 and 2011, at least 250 feet of rock riprap, 4,600 feet of concrete riprap, and 2,200 feet of flow deflectors were destroyed in Region B, primarily by flanking (erosion around and behind the revetments).

Bank armoring has reduced the rates of floodplain erosion and turnover in Region B. The average migration rates measured in Region B dropped from 11 feet per year from 1950-1976 to eight feet per year from 1976-2001. Floodplain turnover rates dropped from 113 acres per year from 1950-1976 to 91 acres per year from 1976-2001, a reduction of 22 percent. The rate of riparian forest erosion in Region B dropped by about 9 acres per year from 1950-1976 to 1976-2001.

Side channels have also been lost in Region B, where a total of 8.9 miles of side channels were blocked by floodplain dikes prior to 1950, and another 6.6 miles have been blocked since. In 1950, there were a total of 122 miles of side channel in Region B, and in 2001, there were 108 miles.

Approximately 2,600 acres or 11 percent of the 100-year floodplain have become isolated in Region B, and most of that is due to the transportation corridor, including the active rail line (1,100 acres) and highways/roads (1,200 acres). About 3,000 acres or 20 percent of the more frequently inundated 5-year floodplain in Region B have become isolated.

High flow alterations in Region B have been moderate. In the lowermost portions of the region just above the mouth of the Bighorn River, the 100-year flood flow has been reduced by about 4 percent, and the 2-year discharge has dropped by about 11 percent.

The impact of human influences on low flows has been more substantial. At the Billings gage, summer baseflows have dropped by about 42 percent, from 3,846 cfs to 2,227 cfs. The low flows and warmer water have exacerbated the effect of nutrient enrichment leading to elevated growth of benthic (attached) algae.

The Huntley and Waco-Custer diversion dams are located in Region B. Huntley Dam is located at a point of split flow on the river, and blocks only the main channel. At low flows, however, the unblocked secondary channels are essentially dry and therefore incapable of passing fish. As part of repairs required after recent flooding on the river, a fish passage channel was constructed around the north end of the dam. At Waco-Custer, the Yellowstone River flows through two main channels, and the structure itself blocks only the right channel. The current status of these structures with respect to fish passage is not clearly known. Sauger have been sampled as far upstream as Billings, which is upstream of both dams.

Region C: Treasure, Rosebud, and Custer Counties

Region C is 149 river miles long, from the mouth of the Bighorn River to the mouth of the Powder River. It includes the entirety of Treasure, Rosebud and Custer counties, as well as about seven river miles of western Prairie County. The area is sparsely populated, with a regional economy highly dependent on agriculture and energy development. In 2010, Treasure, Rosebud, and Custer counties had a combined population of 21,650 people. Region C has experienced only minor changes in land use since 1950.

The cumulative effects in Region C are dominated by the combination of flow alterations and agricultural development on the floodplain. These influences have driven floodplain isolation, bank armoring, riparian clearing, diversion structure construction, and side channel blockage. In turn, these activities have resulted in the reduction in channel size and substantial alterations to aquatic and riparian habitats.

Region C is immediately below the mouth of the Bighorn River and as a result, changes in high flows have been substantial. The 100-year flood flow has been reduced by 16 percent just below the Bighorn River confluence, to 19 percent immediately upstream of the mouth of the Powder River. The 2-year discharge has dropped by about 24 percent. The change in flows in Region C has resulted in a shrinking of the overall Yellowstone River footprint. Between 1950 and 2001, Region C had reduction in total bankfull channel area of 1,092 acres or six percent. In addition, Region C lost 124 acres of mid-channel bar area between 1950 and 2001, as well as about 10 miles of low flow channels

Summer baseflows have dropped by an average of 53 percent in Region C, from 6,483 cfs under undeveloped conditions to 3,434 cfs currently. This major reduction in baseflows has strong implications with respect to water quality and aquatic habitat conditions during summer months.

About 38 percent of the natural CMZ within Region C has been developed, with irrigated agriculture as the primary land use in the CMZ (6,810 acres or 34 percent of total CMZ). The river corridor is also locally followed by the active railroad line and the abandoned Milwaukee Rail Line on the north side of the river; about 360 acres of the CMZ has been consumed by transportation infrastructure.

As of 2011 there were 37.3 miles of bank armor in the region, protecting about 13 percent of the total bankline. Most of that armor (~32 miles) is rock riprap. The majority of the bank armor in the reach (20 miles) is protecting the railroad, and another 10 miles protects irrigated agricultural land. Region C also has 15.8 miles of mapped floodplain dikes and levees. Between 2001 and 2011, at least 230 feet of rock riprap and 7,250 feet of flow deflectors were destroyed in Region C, primarily by flanking (erosion around and behind the revetments).

Bank armoring and flow reductions have dampened erosion rates in Region C, where mean migration rates dropped from 8.1 feet per year from 1950-1976 to 4.9 feet per year from 1976-2001. Similarly, rates of floodplain turnover have dropped from 130 acres per year from 1950-1976 to 90 acres per year from 1976-2001, a reduction of 40 percent. As a result, the rate of riparian forest erosion in Region C dropped by about 25 acres per year.

In 1950, there were a total of 124 miles of side channel in Region C, and in 2001, there were 103 miles. A total of 11.4 miles of side channels were blocked by floodplain dikes prior to 1950, and another 18.8 miles have been blocked since. The 21 mile net loss indicates that there has been some natural recovery from the blockages.

Region C has experienced extensive riparian clearing, due primarily due to expansion of irrigated lands into riparian areas. Between 1950 and 2001 about 10% of the riparian vegetation or 2,200 acres were converted to irrigated land.

About 18,000 acres or 52 percent of the 5-year floodplain in Region C has become isolated due to human influences. Approximately 11,000 acres or 21 percent of the 100-year floodplain has become isolated, and most of that is due to flow alterations (3,400 acres) and agricultural infrastructure such as field dikes (2,900 acres). About 2,300 acres of 100-year floodplain in Region C has become isolated by the abandoned rail line.

There are three in-stream diversion structures in Region C: Rancher's Ditch Diversion, Yellowstone Ditch Diversion, and Cartersville Dam. Cartersville Dam at Forsyth is considered to be a major fish passage barrier, particularly for Shovelnose Sturgeon.

Russian olive extent and density increases in a downstream direction through Region C where saltcedar has also become prevalent throughout the Region.

Region D: Prairie, Dawson, Richland, and McKenzie Counties

Region D is 149 river miles long, from the mouth of the Powder River to the Yellowstone River's confluence with the Missouri River in North Dakota. It includes the river corridor footprint in eastern Prairie County, Dawson County, Richland County, Montana, and McKenzie County, North Dakota. This area is known for both its agricultural importance as well as its rich oil and gas resources. After peaking in the 1980's the economic boom driven by the oil and gas industry experienced a downturn during the 1990's, coincident with drought conditions and a poor agricultural economy through much of the 2000's. However, the oil and gas sector is once again experiencing a boom, resulting in an increase in the population in areas that have previously experienced net out-migration. In 2010, Prairie, Dawson, Richland, and McKenzie Counties had a combined population of 26,251 people.

Similar to Region C, the cumulative effects in Region D are dominated by the combination of flow alterations and agricultural development on the floodplain. These influences have driven floodplain isolation, riparian clearing, diversion structure construction, and side channel blockage. In turn, these activities have resulted in a reduction in channel size, reduction in rates of channel change, and substantial alterations to aquatic and riparian habitats. Bank armoring is relatively rare in Region D.

High flow alterations in Region D have been substantial. The 100-year flood flow has been reduced by about 12 percent, and the 2-year discharge has dropped by about 22 percent. The reduction in stream flows in Region D has affected the size of the river and the rates of bank movement. Between 1950 and 2001, Region D had a reduction in total bankfull channel area of 3,370 acres or 16 percent. The mean migration rates dropped from 9.4 feet per year from 1950-1976 to 4.9 feet per year from 1976-2001. As a result, floodplain turnover rates have dropped from 136 acres per year to 78 acres per year, a reduction of 58 percent. The rate of riparian forest recruitment has dropped by about 12 acres per year. Region D also lost a total of 977 acres of mid-channel bar area between 1950 and 2001, and the length of low flow secondary channels was reduced by 30.1 miles.

The change in low flows has been even more significant. Summer baseflows in Region D have dropped by an average of 45 percent from 6,787 cfs to 3,029 cfs.

About 38 percent of the CMZ within Region D has been developed, with the primary land use in the CMZ of irrigated agriculture (6,876 acres or 35 percent of total CMZ).

As of 2011 there were 9.7 miles of bank armor in the region, protecting about 3 percent of the total bankline. Between 2001 and 2011, at least 450 feet of rock riprap, 1,400 feet of concrete riprap, and 760 feet of flow deflectors were destroyed in Region D, primarily by flanking (erosion around and behind the bank armor structures).

Region D also has 3.2 miles of mapped floodplain dikes and levees, which at 0.02 miles of dikes/levees per river mile, is a relatively low concentration. A total of 11.3 miles of side channels were blocked by floodplain dikes prior to 1950, and another 8.9 miles have been blocked since.

Region D has experienced extensive riparian clearing, primarily due to expansion of irrigated lands into riparian areas. Between 1950 and 2001, about 11% of the riparian vegetation or 2,900 acres were converted to irrigated land.

Approximately 6,800 acres or 14 percent of the 100-year floodplain have become isolated in Region D, and most of that is due to flow alterations (5,000 acres). About 8,300 acres or 40 percent of the more frequently inundated 5-year floodplain in Region D have become isolated.

Region D has the greatest extent of riparian forest on the river, with over 150 acres per valley mile of total forest, and about 140 acres per valley mile of closed timber cottonwood forest. Russian olive extent and density is lower than in Region C.

Intake Diversion Dam is located in Region D. It is the largest diversion dam on the river, and was built in 1911. Previous studies have indicated that approximately 500,000 fish were being entrained into the main irrigation canal annually. Prior to the 2012 irrigation season, the diversion headworks were reconstructed with fish screens, and fish passage issues at this structure are currently being addressed.

Yellowstone River Recommendations

The Yellowstone River, while experiencing the cumulative effects described above, remains a dynamic and ecologically diverse river. Multiple opportunities still exist to ensure the long-term sustainability of the river corridor ecosystem and to maintain the diversity of socioeconomic benefits that the river provides to numerous communities. A number of Yellowstone River Recommended Practices (YRRPs) are summarized in Chapter 8 of this document and explained in more detail in the companion document -- *Yellowstone River Recommendations – Practical Applications with a Cumulative Effects Perspective - 2015.*

The Yellowstone River Recommended Practices include the following:

- Isolated Floodplain Restoration – Agricultural and Urban/Residential Development
- Isolated Floodplain Restoration – Active/Abandoned Railroads and Public Roads
- Side Channel Blockage Removal
- Channel Bank Stabilization
- Riparian and Wetlands Management
- Invasive Woody Plant Control
- Noxious Weed Control

- Water Quality – Nutrient Reduction: Agricultural Land Use
- Water Quality – Nutrient Reduction: Residential Development
- Solid Waste Removal
- Irrigation Water Management
- Oil/Gas/Brine Water Pipeline Crossings
- Altered Flows
- Channel Migration Zone
- Fish Passage and Entrainment

The companion document *Yellowstone River Recommendations – Practical Applications with a Cumulative Effects Perspective – 2015* outlines an Implementation Strategy and identifies additional data needs. The Yellowstone River Conservation District Council (YRCDC) and U.S. Army Corps of Engineers (Corps) will continue to identify opportunities to partner with individuals, groups, organizations, and agencies to implement recommendations from this study.

This Cumulative Effects Analysis Report presents in detail the data and logic for the above findings of cumulative effects on the Yellowstone River Corridor. This document and supporting appendices (provided in a separate volume), prior study reports, and GIS database are available as resources for local, state, federal, and tribal agencies, stakeholders, and the general public to use to improve their management of the river and its floodplain. The goal is to ensure that important environmental, economic, and cultural values can be sustained for the long-term benefit of the citizens within the watershed.

Report Organization

This document consists of 11 chapters:

Chapter 1, Introduction—Provides background information including description of the study area, authorization, study participants, and the scope of the study.

Chapter 2, Natural and Human History of the Yellowstone River Corridor—Includes an overview of the natural history of the Yellowstone River corridor and implications for this study.

Chapter 3, Study Area and Study Reaches—Summarizes the development of reach narratives for specific segments of the Yellowstone River and of a supporting database.

Chapter 4, Primary River Element Cause-and-Effect Analysis—Analyzes causes and effects for the primary river elements addressed in the study, including descriptions of the affected environment and impacts of various stressors.

Chapter 5, Socioeconomics—Describes the economic profiles of the counties in the study area, the economic sectors, and a summary of a cultural values survey that was conducted of study area residents.

Chapter 6, Cumulative Effects Analysis by Land Use—Describes the cumulative effects resulting from various land uses.

Chapter 7, Primary Cumulative Effects—Describes the primary cumulative effects.

Chapter 8, Recommendations—Includes recommendations such as Management Practices and possible restoration opportunities for consideration.

Chapter 9, Public Participation and Tribal Coordination—Describes the public participation process and tribal coordination that occurred during the study.

Chapter 10, List of Authors.

Chapter 11, References.

Accompanying appendices and datasets are provided in a separate volume. The appendices include:

Appendix 1 - Land Use

Appendix 2 – Hydrology

Appendix 3 – Floodplain Connectivity

Appendix 4 – Geomorphology

Appendix 5 – Water Quality

Appendix 6 - Terrestrial Plants (Riparian Systems)

Appendix 7 – Aquatic Plants (Wetland Systems)

Appendix 8 – Fisheries

Appendix 9 – Avian

Appendix 10 – Socioeconomics

- Yellowstone River Cultural Inventory- 2006
- Socioeconomic Report: Regional Profile of the Yellowstone River Corridor
- Socioeconomic Report: Analysis of Agriculture, Urban/Ex-Urban Development and Transportation Sectors
- Socioeconomic Report: Analysis of Ecosystem Services in the Yellowstone River Corridor and Economic Impacts of Tourism and Yellowtail Dam

Appendix 11 – Reach Narratives

Appendix 12- Public and Tribal Coordination

1.0 INTRODUCTION

The Yellowstone River Cumulative Effects Analysis (CEA) Study is a study led jointly by the Yellowstone River Conservation District Council (YRCDC) and the U.S. Army Corps of Engineers (Corps). In 2004, the Corps and YRCDC entered into a cost-share agreement to conduct a comprehensive study of the mainstem Yellowstone River from Gardiner, Montana to the confluence of the Missouri River in North Dakota. This study is referred to as the Cumulative Effects Analysis (CEA) throughout this report.

1.1 Project Location

The study area includes the Yellowstone River corridor from Gardiner, Montana to the confluence with the Missouri River in North Dakota. The river corridor spans the 12 counties of Park, Sweet Grass, Stillwater, Carbon, Yellowstone, Treasure, Rosebud, Custer, Prairie, Dawson, and Richland in Montana and McKenzie in North Dakota. Figure 1-1 shows the Yellowstone River watershed along with the counties that make up the river corridor. The river is approximately 700 miles long, with this analysis covering the lower 565 river miles from Gardiner, Montana at the northern boundary of Yellowstone National Park to the confluence with the Missouri River in North Dakota. The area of analysis focuses on the river and its approximately 200,000 acre floodplain.

The Yellowstone River watershed covers approximately 71,000 square miles with a wide expanse of tributary and mainstem headwaters in Wyoming, gradually narrowing to join the Missouri River in far western North Dakota. Watershed elevations range from up to 13,000 feet in the Wind River Range, Wyoming, to around 2,000 feet near the confluence with the Missouri River in North Dakota.

1.2 Study Participants and Coordination

The CEA is a river corridor study led jointly by the Corps and YRCDC. Over the eleven years of the study, participation has included federal, state, local agencies, state universities, private consultants, and non-government organizations. Throughout this time, representation has remained remarkably stable, with many of the core project team members active from start to finish. For the first few years, efforts focused on developing a suite of strategically integrated, multi-disciplinary scopes of work that form the core of the study. Parallel efforts were undertaken to secure funding and to develop an implementation strategy for each scope. As individual study components were performed, they were closely tracked and evaluated with respect to implications regarding potential cumulative effects on the river system. This required regular meetings and the consistent involvement of project participants. A major effort was made to continually include all involved CEA participants in interdisciplinary discussions of cumulative effects.

The CEA process also included the creation of interim products that the project participants considered valuable to the public. These products included a web-based interactive map viewer that allows stakeholders to view information generated by the study, including Channel Migration Zone maps that were developed as part of the study, and made available to the public immediately on their completion. Project datasets and reports have been continually posted on the Yellowstone River Corridor Resource Clearinghouse website hosted by the Montana State Library, to make them available to the general public as promptly as possible (Montana State Library 2015). These datasets include imagery, physical and biological inventories, floodplain analyses, and an array of summary reports.

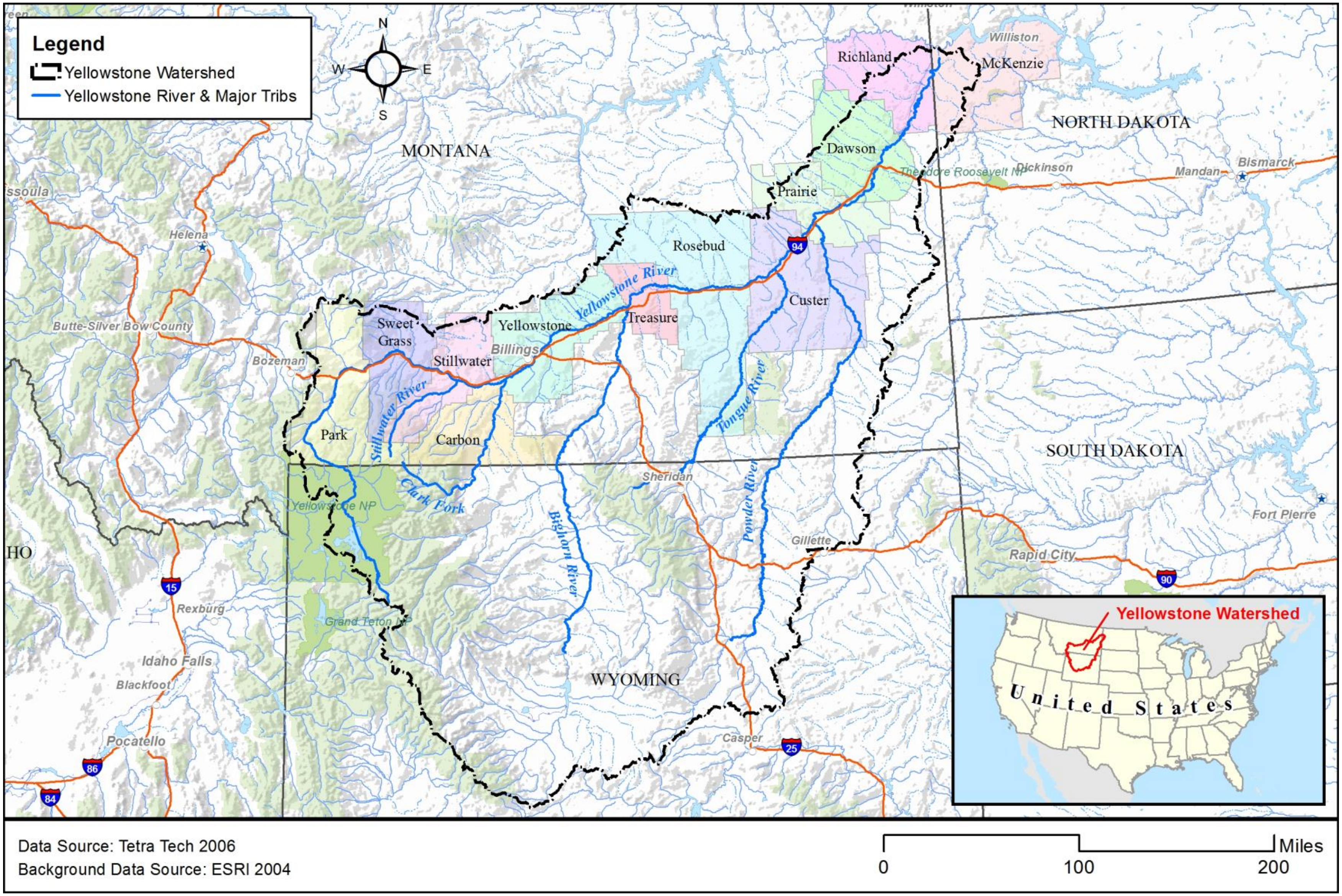

Figure 1-1 **Study area and entire Yellowstone watershed**

The CEA included several project outreach efforts that were designed to raise public awareness and garner feedback throughout the study. These efforts included workshops held throughout the corridor and conferences developed specifically for the CEA. Annual regional tours by boat, train, and vehicle (Figure 1-2) were held to promote collaboration and understanding of the river and its people, and the convergence of the two into the CEA. Ultimately, this effort resulted in a remarkable level of interdisciplinary collaboration with regard to project development, execution, and ultimate completion. Those involved in this effort have had the opportunity to work with a uniquely committed and competent group of people who all have shown remarkable resilience and dedication towards the completion of this vast effort.

Figure 1-2 YRCDC boat tour at Intake Dam, Montana (2013)

1.2.1 Yellowstone River Conservation District Council

The Yellowstone River Conservation District Council (YRCDC) has provided key local representation to the CEA. The council was formed in 1999 specifically in support of the CEA, and is made up of representatives from eleven Conservation Districts located within the river corridor (Figure 1-3). The Montana Conservation Districts represented on the YRCDC include: Custer, Dawson, Park, Prairie, Richland, Rosebud, Stillwater, Sweet Grass, Treasure, and Yellowstone Counties. Additional YRCDC membership includes one representative each from McKenzie County, North Dakota, and the Montana Association of Conservation Districts. The Council has two committees that serve key functions: the Technical Advisory Committee (TAC) and the Resource Advisory Committee (RAC). The Chair of the RAC also serves on the YRCDC.

Figure 1-3 Yellowstone River Conservation District Council Members

1.2.1.1 Yellowstone River Technical Advisory Committee

The Technical Advisory Committee has taken the lead in assisting the YRCDC and the Corps in the development and oversight of the technical studies contained in the Study's Project Management Plan. The Technical Advisory Committee meets bi-monthly to review budget allocations, review and revise schedules, develop and/or review work contracts, advise the YRCDC on progress and issues, monitor compliance with quality-control procedures, coordinate work to resolve any issues that impede progress or quality of work, ensure opportunity for public participation and review of products, and interface with the stakeholders and the general public on a routine basis. The Technical Advisory Committee facilitates the development of timely, quality products within the established task budget. Representatives from the Corps, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Geological Survey, Montana Fish Wildlife and Parks, Montana Department of Natural Resources and Conservation, YRCDC, The Nature Conservancy, Montana State University-Billings, and natural resource consultants have served on the Technical Advisory Committee throughout part or all of the study.

1.2.1.2 Yellowstone River Resource Advisory Committee

The Resource Advisory Committee is made up of stakeholders from a representative array of interest groups and local government entities associated with the Yellowstone River. It provides the following support to the YRCDC:

- Provides local input and recommendations to the YRCDC regarding Cumulative Effect Analysis studies of the Yellowstone River;
- Serves as advisor to the YRCDC and provides an avenue of communication and cooperation between the various interests on the Yellowstone River;
- Proposes evaluation strategies, studies, and actions for improving the understanding, management, and conservation of the river and its resources;
- Reviews and provides input on management practices and other recommendations promoted by the YRCDC as a result of the Cumulative Effects Analysis.

1.2.2 U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (Corps) Omaha District has served as principal federal agency providing financial resources, technical expertise, and management in partnership with the YRCDC and its committees. The Corps, in partnership with the YRCDC, has had primary responsibility for developing the Project Management Plan, establishing budgets for the component technical studies, and tracking schedules. Through the terms of the cost-sharing agreement, the Corps and YRCDC have jointly secured financial resources ensuring successful completion of the study. The Corps is a member of the TAC and has regularly attended both YRCDC and TAC meetings, and topic specific technical meetings as necessary, helping to lead discussions on the scope and quality of work products and how the results link to a better understanding of cumulative effects. The Corps has also provided periodic status updates to Congressional offices in response to inquiries.

1.3 Other Relevant Studies

The Yellowstone River has received increased public attention in recent years due to the combined effects of damaging flood events and increased development pressures within the river corridor. Major flood events in 1996 and 1997 resulted in an increased awareness of the potential magnitudes of Yellowstone River flooding and bank erosion, as well as associated threats to infrastructure and land use. This resulted in several related, but separate, efforts within the watershed.

1.3.1 Upper Yellowstone River Task Force

Following the consecutive flood events in 1996 and 1997, the Governor of Montana appointed the Upper Yellowstone River Task Force in an effort to provide a forum to discuss issues affecting the river. Between 1997 and 2003, the Task Force conducted an interdisciplinary study to assess the cumulative effects of bank stabilization and natural and other channel modification on the physical, biological, and cultural attributes of the Upper Yellowstone River, which extends from the Yellowstone National Park boundary at Gardiner, Montana, to the bridge at Springdale, Montana (Park County). In 2003, the Task Force completed its work and submitted 43 consensus-based recommendations, documents, and information (Montana State Library 2015).

1.3.2 Special Area Management Plan

In May 1999, a group of environmental organizations initiated a lawsuit against the Corps, which claimed the Corps needed to better consider the cumulative effects of bank stabilization repairs on the integrity of the riverine ecosystem. In May 2000, a U.S. District Court judge ordered the Corps to reopen 14 permits and revisit the cumulative impact analyses for the repair. In response to the lawsuit and court decision, the Corps continued accepting and evaluating permit applications, but an enhanced cumulative impact analysis was applied on all subsequent permit reviews. The Corps completed the Upper Yellowstone River Special Area Management Plan (SAMP) and associated environmental assessment with a Finding of No Significant Impact in April 2011. The SAMP applies to a 48-mile reach of the upper Yellowstone River in Park County (i.e., Emigrant to Mission Creek) that is more susceptible to the cumulative impacts of bank stabilization activities. The Special Area Management Plan information can be found on the Corps' Omaha District webpage (Corps of Engineers 2015).

1.4 Authorization

The Yellowstone River Corridor Study was initiated in response to the 1999 Water Resources Development Act (WRDA) authorization. The Corps completed a 905(b) Analysis Report, which recommended a feasibility study of the river corridor to address issues that are beyond the capability of state and local interests to resolve, given the existing circumstances and conflicts regarding water and related land resources issues in the two-state, multi-county region. The Corps Headquarters approved that 905(b) report on August 13, 2002.

1.4.1 Primary Study Authorization

The CEA was authorized by Section 431 of the Water Resources Development Act of 1999. Language from WRDA directing the Assistant Secretary of the Army (Civil Works) to conduct the study is as follows:

SEC. 431 YELLOWSTONE RIVER, MONTANA.

> ***(a) Study.*** *The Secretary shall conduct a comprehensive study of the Yellowstone River from Gardiner, Montana to the confluence of the Missouri River to determine the hydrologic, biological and socioeconomic cumulative impacts on the river.*
>
> ***(b) Consultation and Coordination.*** *The Secretary shall conduct the study in consultation with the U.S. Fish and Wildlife Service (USFWS), the U.S. Geological Survey (USGS) and the Natural Resources Conservation Service (NRCS) and with the full participation with the State of Montana and tribal and local entities, as well as public participation.*
>
> ***(c) Report.*** *Not later than five years after enactment of this Act, the Secretary shall submit to Congress a report on the results of this study.*

1.4.2 Related Authorization

Additional authority for restoration projects within the study area was provided by Section 3110 of the Water Resources Development Act of 2007. This authority provides a potential avenue to study and implement specific recommendations from this study in the future.

SEC. 3110. YELLOWSTONE RIVER AND TRIBUTARIES, MONTANA AND NORTH DAKOTA.

(a) DEFINITION OF RESTORATION PROJECT.—In this section, the term ''restoration project'' means a project that will produce, in accordance with other Federal programs, projects, and activities, substantial ecosystem restoration and related benefits, as determined by the Secretary.

(b) PROJECTS.—The Secretary shall carry out, in accordance with other Federal programs, projects, and activities, restoration projects in the watershed of the Yellowstone River and tributaries in Montana, and in North Dakota, to produce immediate and substantial ecosystem restoration and recreation benefits.

(c) LOCAL PARTICIPATION.—In carrying out subsection (b), the Secretary shall—

(1) consult with, and consider the activities being carried out by—

(A) other Federal agencies;

(B) Indian tribes;

(C) conservation districts; and

(D) the Yellowstone River Conservation District Council; and

(2) seek the participation of the State of Montana.

(d) AUTHORIZATION OF APPROPRIATIONS.—There is authorized to be appropriated to carry out this section $30,000,000.

1.5 Study Scope

In order to meet the direction of the study authority provided by Congress, a multi-agency team, in coordination with the YRCDC, developed a scope of work to characterize the hydrologic, biological and socioeconomic conditions on the river and assess the relationships between them. The overall study consists of the following major tasks, each of which were managed as individual work scopes:

1. Project Management
2. Public Participation
3. Tribal Coordination
4. Biological Studies
5. Socioeconomics
6. Data and Topography Mapping
    a. GIS and Information Management

   b. Topographic and Bathymetric Mapping

7. Hydrology
8. Hydraulics
9. Geomorphology
10. Cumulative Effects
11. Report Distribution
12. Program Management.

Project Management, Public Participation, Tribal Coordination, Program Management and Report Distribution lay out the process of how the study will be conducted, documented, and coordinated. The remaining tasks address the technical work necessary for building a comprehensive analysis of cumulative effects in the river corridor. The following is a summary of the technical analyses scopes.

1.5.1 Biological Studies

1.5.1.1 Riparian

The primary purpose of the riparian analysis is to gain an understanding of the plant community composition, structure, and dynamics along the Yellowstone River riparian corridor and to evaluate the interrelationships that the riparian plant community has with invasive plant species infestations, channel geomorphology, river hydraulics, and in-channel fish habitat. The analysis identifies temporal and spatial changes in riparian vegetation as well as invasive species and their impacts on riparian communities in the corridor.

1.5.1.2 Wetlands

The purpose of the wetland analysis is to investigate the cumulative effect of human activities along the Yellowstone River on the abundance and/or quality of wetlands. The study discusses the spatial distribution of wetland vegetation, spatial changes in wetland extent and distribution, ecological significance of wetlands, and the impact of invasive species on wetlands in the corridor. Historical wetland data does not exist, so a temporal analysis was not possible.

1.5.1.3 Avian

The purpose of the avian study is to evaluate how cumulative human factors influence avian populations and communities along the Yellowstone River. The analysis includes the spatial distribution of general avian responses, impacts of habitat condition on avian responses, and status and trends of habitat conditions along the Yellowstone River.

1.5.1.4 Fisheries

The purpose of the fisheries study is to evaluate how human influences affect the fish assemblage using published studies, unpublished reports and professional judgment. The analysis discusses changes in the physical river system (altered hydrology, geomorphology, riparian vegetation, wetlands, land use, connectivity, water quality, introduced species, and recreational fishing) and how those changes influence fisheries in the Yellowstone River.

1.5.1.5 Water Quality

The water quality study provides a description of the existing state of water quality in the Yellowstone River and a discussion of human influences on water quality. It presents key information from the USGS SPARROW (Spatially Referenced Regression on Watershed Attributes) surface water quality model to estimate nitrogen and phosphorous yields and quantify the importance of various nutrient sources. The model uses calibrated models to predict long-term average loads, concentrations, yields, and source contributions for all stream reaches (monitored and unmonitored) within the modeled watersheds.

1.5.2 Socioeconomics

The purpose of the socioeconomic analysis is to provide a detailed regional profile that synthesizes available data relevant to different socioeconomic conditions at various time intervals. It expands on the regional profile with emphasis on the transportation sector, urban/exurban development, and the agriculture industry. The analysis provides economic relevance to the biophysical findings in the cumulative effects analysis. Analysis using the Yellowstone River Cultural Inventory was completed in 2006 as part of the scope of the cumulative effects analysis, which documents the different perspectives and values held by people who share the Yellowstone River.

1.5.3 Data and Topographic Mapping

The Data and Topographic Mapping scope includes the collection, creation, and analysis of spatial data, as well as the archiving and dissemination of project data and reports.

1.5.3.1 GIS and Information Management

The purpose of the Geographic Information System (GIS) and information management scope is to provide a means to communicate information and results of the project to the public, the YRCDC, and investigators working on the project. This work includes database design and data development services, electronic data storage and retrieval, data sharing among scientific investigators, Internet access to final products resulting from the project, and map-rendering services to assist in communicating results of the analysis. A data clearinghouse is housed at Montana State Library, and can be found at the following; http://geoinfo.msl.mt.gov/Home/data/yellowstone_river_corridor_resource_clearinghouse. All project data and reports will be housed at this site.

1.5.3.2 Topographic and Bathymetric Mapping

This effort includes the development and acquisition of aerial imagery, elevation, and bathymetric data of the study area. Data acquisition included LiDAR elevation data for Springdale to the Missouri River Confluence, with high-resolution color imagery collect in parallel with the elevation data. Bathymetric mapping was collected for sections of Stillwater, Yellowstone, and Dawson Counties. The new mapping provides baseline data that is in the hydraulic analyses, as well as supporting analysis for other project scopes.

1.5.4 Hydrology

The hydrologic analysis (by the Corps and USGS) develops the hydrologic data necessary to evaluate the water-related issues in the Yellowstone River basin. The primary objective of the hydrology analysis is to establish the discharge frequency and flow-duration relationships for the Yellowstone River from Park County to the confluence with the Missouri River near Williston, North Dakota. This information serves as the foundation for understanding the Yellowstone River hydraulics, geomorphology, and ecosystem.

1.5.5 Hydraulics

The hydraulic analysis provides hydraulic information to define the current and historical extent of the Yellowstone River floodplain for multiple purposes:

- To identify opportunities to reduce flood damage;
- To determine impacts from human development;
- To restore environmental features and functions.

In addition, the analysis provides detailed hydraulic data, including river stages, velocities, flow depths, and flooded areas in support of the geomorphic and biological analyses for the study.

1.5.6 Geomorphology

The primary purpose of the geomorphic analysis is to assess the fluvial geomorphology of the Yellowstone River to determine how channel behavior is related to both natural processes and human impacts. The analysis includes a detailed assessment of the geomorphic processes characteristic of representative reaches, including a relative channel stability assessment and an evaluation of rates and trends of geomorphic evolution. These geomorphic trends are assessed with respect to both observed hydrologic changes and identified river controls (floodplain encroachments, bank stabilization, grade controls, etc.).

1.5.7 Cumulative Effects

The cumulative effects analysis utilizes all of the technical analyses conducted in the other scopes to develop a characterization of cause-and-effect relationships between human activities and associated river system responses. The cause and effect relationships are then used to develop recommendations for management practices and actions that will provide sustainability to socioeconomic interests while maximizing the long-term biological and physical integrity of the river system. To the extent possible, the cumulative effects analysis relies on a scientific foundation to understand cumulative cause-and-effect relationships of human actions and natural processes. The decision-making process was based on this scientific foundation and integrated stakeholder values.

2.0 NATURAL AND HUMAN HISTORY OF THE YELLOWSTONE RIVER CORRIDOR

This chapter provides an overview of the Yellowstone River setting. The main topics include (1) what is known about natural history and how it is applied to the Yellowstone River and (2) how communities' culture and economic use of the Yellowstone interact with the natural history. This is not intended as an encyclopedic coverage of natural history in the Yellowstone River watershed. Rather it touches on some main points of geology, climate, biology, and the principal economic uses of the Yellowstone River corridor.

2.1 Natural History

The natural history of a river includes all of the natural elements that make up a watershed. At the most basic level, a watershed is the contributing basin to a stream or river system, including its floodplain and upland areas.

The Yellowstone River corridor crosses the semi-arid temperate steppes of North America, but the upper watershed includes high-elevation and relatively high-precipitation mountain ranges, similar to the Missouri River and other major rivers in the region. The natural history of all these rivers of the Northern Rocky Mountains has been studied to some extent. Their main features are well-known, and the interdependency of water, geology, and biology are generally predictable.

The nearly 700-mile-long Yellowstone River is the largest tributary to the Missouri River. Its mean annual discharge is 12,747 cubic feet per second (cfs), about 55 percent of the Missouri River's total water volume at the confluence. The Yellowstone and its regional relatives all derive the majority of their water from mountain snowmelt and begin as coldwater mountain streams with rocky beds. The rivers gradually transition to lower-gradient, small gravel to sand beds with warmer water. While roughly half of the land area ultimately drained by the Yellowstone watershed lies in Wyoming, the Yellowstone River itself is contained almost entirely within Montana.

As a national resource, the Yellowstone is without parallel. The river originates in the nation's first national park (Yellowstone National Park) and it is referred to as the longest free-flowing river in the lower 48 United States, as there are no major dams or reservoirs on the mainstem river. It is nestled within the largest relatively intact temperate zone ecosystem on the planet, the Greater Yellowstone Ecosystem (Jean and Crispin 2001). Between Gardiner and the Yellowstone River/Missouri River confluence, the physiography of the Yellowstone River and its tributaries transitions from steep, confined mountainous areas to plains conditions. This physiographic transition correlates to a transition from a salmonid-dominated fishery in the upper reaches to a warmwater fishery in the lower reaches. The watershed supports over 200 plant and animal species of conservation concern. In addition to its ecological importance and scenic beauty, the Yellowstone supports a variety of agricultural, domestic, industrial, and recreational uses. These uses are of great economic and social importance, both to the nation, and the people who live along the river (YRCDC 2013).

2.1.1 Physiography

The Yellowstone River watershed covers approximately 71,000 square miles, with headwaters in Wyoming and Montana. It joins the Missouri River in far western North Dakota. The physiography of the Yellowstone Watershed is quite diverse, and it includes three physiographic provinces: the Great Plains, Middle Rocky Mountains, and Northern Rocky Mountains (Zelt et al. 1999).

The Great Plains Province is composed of gently rolling hills with some sharply dissected badlands, a product of easily eroded shale. Elevations in the Great Plains region of the watershed range from 7,217 feet to 1,870 feet near the confluence with the Missouri River. The majority of the watershed lies in the unglaciated portion of the Missouri Plateau section of the Great Plains province. The topography of the unglaciated portion was formed for the most part by fluvial dissections of outwash plain. The extreme northeastern edge of the Yellowstone Watershed was exposed to continental glaciation.

The Middle Rocky Mountains Province features landforms such as mountain ranges, high plateaus, and inter-mountain basins. Elevations range from 3,400 feet to 13,700 feet. Within the Yellowstone Watershed lie the Absaroka Range, the Beartooth Mountains, the far north reach of the Bighorn Mountains, and the Pryor Mountains. The Bighorn Mountains are broad anticlines flanked by hogbacks. The Beartooth Mountains are high plateaus that sit on top of several uplifted blocks dissected by glaciated river valleys. The Absaroka Range consists of volcanic deposits that produce a rugged topography that consists of steep valleys with erodible slopes (Zelt et al. 1999).

The Northern Rocky Mountain Province is separated from the Middle Rocky Mountain Province by the Yellowstone River Valley and Yellowstone Plateau. The Yellowstone River flows out of the highland alpine areas and into the Great Plains, which are primarily underlain with sedimentary rock with glacial outwash and alluvium common throughout (Jean and Crispin 2001).

2.1.2 Climate

Climate of the Yellowstone watershed (as described in Zelt et al. 1999) ranges from cold and wet in the mountains to temperate and semi-arid in the plains. Mean annual temperatures range from less than 0ºC (32ºF) to 10ºC (50ºF), with temperatures coldest in January (average temperatures ranging from -18ºC (0ºF) to -3°C (27ºF) and warmest in July (average temperatures ranging from 12ºC (54ºF) to 24ºC (75ºF). Average frost-free periods range from 10 days at high elevations to 140 days in lower basins. Precipitation is variable and depends on the region. The Absaroka and Beartooth Mountains receive 40 to 110 inches of precipitation a year. The Great Plains region receives 10 to 20 inches of precipitation a year. Snowfall makes up a considerable portion of the annual precipitation. Variability of precipitation is more pronounced in the plains than in the mountains.

2.1.3 Vegetation

Vegetation communities (largely described in Jean and Crispin 2001) vary greatly and include the following major types:

- Alpine tundra includes turf vegetation dominated by Ross' avens (*Geum rossii*), curly sedge (*Carex rupestris*), Bellardi bog sedge (*Kobresia myosauroides*), and blackroot sedge (*Carex elynoides*); cushion plant communities dominated by curly sedge, moss campion (*Silene acaulis*), dwarf clover (*Trifolium nanum*), and twinflower sandwort (*Minuartia obtusiloba*); and wet meadows dominated by tufted hairgrass (*Deschampsia cespitosa*), alpine bluegrass (*Poa alpina*), and Parry's clover (*Trifolium parryi*).

- Coniferous forests mostly dominate the mountainous regions and include whitebark pine (*Pinus albicaulis*), subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmannii*), and lodgepole pine (*Pinus contorta*). Lower elevated montane areas contain Douglas fir (*Pseudotsuga menziesii*) and lodgepole pine, with ponderosa pine (*Pinus ponderosa*) lower still.

- Deciduous forests are not common but do occur in the lower montane zone. They are largely composed of aspen (*Populus tremuloides*) or cottonwood (*Populus balsamifera ssp. trichocarpa* or *Populus deltoides* and *Populus angustifolia*).

- Grassland and shrublands are found in the valleys and plains and include Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Pseudoroegneria spicata*), and needle-and thread (*Hesperostipa comata*).

- Sagebrush communities are found in upland sites and include mountain sagebrush (*Artemisia tridentata ssp*. *vaseyana*) and the more arid big sagebrush (*Artemisia tridentata spp*. *tridentata*).

- Intermountain wetlands (as described in Jones 2001) are found in glacial cirques and kettles. Floodplain and depressional wetlands have developed in glaciated valleys and wind-eroded deflation basins.

- Willow shrublands are found in floodplains, around beaver ponds, in peatlands, and surrounding pot-holes and lakes.

- Non-willow shrublands include mountain alder (*Alnus incana*) and water birch (*Betula occidentalis*) in springs and seeps along streams; and Western snowberry (*Symphoricarpos occidentalis*), silver sagebrush (*Artemisia cana*), chokecherry (*Prunus virginiana*), and red-osier dogwood (*Cornus stolonifera*) are common along riverine floodplains.

2.1.4 Wildlife

The diversity of the landscape leads to a variety of habitats for animal species. Mountainous habitats have associated plants and animals adapted to cold water and high altitude climate. Lower altitude habitats support associated plant and animal species able to exist in a continental climate with hot summers and cold winters. General fauna (as described by Jean and Crispin 2001) includes elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus)*, bighorn sheep (*Ovis canadensis*), antelope (*Antilocapra americana),* and bison (*Bison bison*).

Species of concern are numerous within the Yellowstone Watershed. The coniferous forest ecosystem is a remaining stronghold of habitat for the gray wolf (*Canis lupus*), grizzly bear (*Ursus arctos horribilis*), and North American lynx (*Lynx canadensis*), although historically, bears and wolves ranged widely across the Great Plains as well. The gray wolf has been removed from the Endangered Species list in Montana, but on February 20, 2015 it was put back on the Endangered Species List for Wyoming (USFWS 2015a). Grizzly bears and lynxes are still listed as threatened. State listed species of concern include the fisher and wolverine. State listed bird species of concern include the goshawk (*Accipiter gentiles*), black-backed woodpecker (*Picoides arcticus*), and white-winged crossbill (*Loxia leucoptera*), all of which require large intact habitats.

The riverine system and riparian habitats support an outstanding trout fishery as well as other state species of concern, which include the cutthroat trout (*Oncorhynchus clarki bouvieri*) and sauger (*Stizostedion canadense*). Reptile species of concern include the snapping turtle (*Chelydra serpentina*) and spiny softshell (*Trionyx spiniferus*). Amphibian species of concern include the Columbia spotted frog and the Northern leopard frog (Figure 2-1). Bird species of concern associated with wetlands include the bald eagle (*Haliaeetus leucocephalus*), harlequin duck (*Histrionicus histrionicus*), and the redheaded woodpecker (*Melanerpes erythrocephalus*).

Grassland species of concern include two candidates for listing by the USFWS: the black-tailed prairie dog (*Cynomys ludovicianus*) (USFWS 2011) and the greater sage grouse (*Centrocercus urophasianus*) (USFWS 2015b). Historically, bison were present in large herds that migrated widely through the basin. Their presence likely had a substantial effect on the vegetation communities and river morphology through short periods of intensive grazing and disturbance from river crossings.

Figure 2-1 Northern leopard frog

2.1.5 Mainstem Ecology

The Yellowstone River is the only river of major size and length in the lower 48 states that does not have a large-scale dam and reservoir interrupting its mainstem natural features. As the river makes its way down the valley, it interacts with its geology and sediment supply, the amount of precipitation, climate, and steepness of the valley to form the natural river features and human occupation patterns in place today.

In general, the riverside vegetation is dominated by riparian cottonwood forest wherever the river meanders and forms bars and other landforms that are near water level. The forests vary substantially in age, based on when the river meandered and new growth of seedlings appeared. At any point in time, depending on how recently the river has moved, the immediate vicinity may be composed of bare ground, grasslands, newly seeded forest tree species, shrubs, closed forest, or maturing old and decadent open forest. While cottonwoods dominate, there may also be willow, green ash, box elder, dogwood, and other species intermixed with the cottonwood. The mainstem riparian plant community transitions from narrowleaf/black cottonwood to plains cottonwood to green ash.

Associated with the river, riparian zone, and floodplain are a wide variety of terrestrial wildlife species. While there is a large range of mammals, as listed above, this study concentrates on bird species that are dependent on the riparian, wetland, and aquatic habitats along the river. There is some variation in bird species from the river's headwaters to its junction with the Missouri River in northwestern North Dakota, although there is continuity of many species. These mainly migratory species spend the warm months along the river and migrate south for the colder time of year. They are sensitive to a range of habitat conditions, such as density of forest, variety in heights of vegetation, and openings in and intrusions into the natural forest areas. Birds are a good indicator of the health and intactness of the riparian and floodplain habitats along the river.

The waters of the river also contain a diverse set of aquatic life forms, supporting an array of invertebrate, amphibian and fish species. The fish species differ significantly from the upper river to the lower. The fish species assemblage is salmonid-centered in the cold waters of the upper Yellowstone and limited to under 20 species. The warmer waters of the lower reaches of the river support a more varied warmwater fishery, numbering some 50 species. The transition from cold to warm primarily occurs between Laurel and the mouth of the Bighorn River in the central region of the Yellowstone corridor. There is also aquatic and emergent vegetation in the Yellowstone River, which occurs in wetlands adjacent to the river as well as in the river itself. The waters of the river play a pivotal role in distributing seeds to new landforms along the river.

2.1.6 Example of River Ecology: Woody Debris

A watershed in its natural state demonstrates an interconnectedness in how various plants and animals live through their life cycle and interact with other species' growth and habitat. One example from the Yellowstone watershed is the relationship between large cottonwood trees and the rivers' fisheries. When cottonwood trees fall or are washed into the river channel, they become host habitat for a variety of invertebrates that gradually decompose the trees (further contributing nutrients to the aquatic food web). In turn, many species of fish feed on the invertebrates and use the woody debris as shelter from the swift Yellowstone current.

The woody debris has other natural history aspects, such as an effect on morphology of the stream. The accumulation of woody debris in the channel can affect sediment deposition and erosion patterns, as mid-channel bars commonly form in the lower velocity zone downstream of lodged cottonwood trees (see Figure 2-2). These islands are typically colonized by new riparian forest, which contributes to a range of age classes in the stream corridor that supports a range of bird species.

Woody debris is just one of many individual factors that create a complex process of a river's movement through its valley, its interactions with its geology, hydrology and climate, and the biology that develops within the bounds of precipitation, temperatures, soil types, valley width, and other factors.

Figure 2-2 Large woody debris jams helping to create islands and mid-channel bars by trapping sediment

Note: *These features provide riparian and wetland habitat when above the ice scour elevation, as well as important, seasonal fisheries habitat.*

2.2 Economics and Community Development

The Yellowstone watershed was relatively unaffected by human activities prior to the 19th century. The Native American people living in the Yellowstone River environs were few in population and did not have permanent settlements. They subsisted on hunting of game both large and small and the gathering of native plants and their roots, seeds and berries. Because of the small populations, the lack of firearms, and the lack of major means of transport until the 19th century, these hunter and gatherer cultures had minor effects on the Yellowstone River corridor, as they took no water other than drinking water and did not seek to control the size or direction of the river's flow (Schneiders 2003). They only affected vegetation communities through low-intensity fires.

While not the first Euro-American party to travel through this area, the Lewis and Clark Expedition of 1804 through 1806 was the first to systematically document the area and its natural features. Two other exploratory expeditions, both military-sponsored, reached portions of the Yellowstone—first in 1859 to about the mouth of the Tongue River, and then in the mid-1870s when the steamboat Josephine almost reached the mouth of the Clarks Fork River near present-day Billings. Exploration was mainly intended to reveal travel routes that might serve a function similar to that of the Oregon Trail, moving settlers to resources further west. In general, the Yellowstone country was viewed as a vast, dry desert-appearing country where only the river bottoms possessed a variety of vegetation and game animals.

While the trapping of fur-bearing animals and the discovery of gold and other precious minerals began spurring the settlement of western Montana by the mid-19th century, the Yellowstone country was still recognized as Native American territory by the American government. Sporadic settlement began in the valley after the Indian Wars of the 1870s, but the construction of the Northern Pacific Railroad up the Yellowstone Valley in 1881 and 1882 introduced two of the economic sectors—agriculture and transportation—that would become mainstays of the Yellowstone Valley economy and drive much of its settlement. The Northern Pacific Railroad was a land grant railroad, with sections of land granted to the company as an incentive to build the transcontinental connection. Those lands were used to generate income for the railroad company. One way to do that was to begin the development of farming infrastructure such as irrigation, sell land to prospective settlers, and then convey farming commodities from the land sold in this manner. In addition to the railroads, the Homestead Act (starting in 1862) encouraged settlement of the West.

For the purpose of this river corridor study, the most pertinent outcome of the railroad construction and settlement activity was irrigated agriculture and ranching along the entire Yellowstone River Valley. Certain centers became more important than others. The railroad founded division points at Glendive, Billings, and Livingston. By 1883, Livingston with its two points of attraction (machine shops for the railroad and position as the gateway to Yellowstone National Park, established in 1872), was the largest town in the valley with 2,000 residents.

However, Billings was to later become the center of population and commerce for the entire Yellowstone Valley. Between 1894 and 1908, a number of trends in American economics combined to make Billings expand. With the Northern Pacific Railroad already in place, the Burlington and Great Northern Railroads added connections to the north (Great Falls), south (Denver), and east (Omaha) that would make the Billings–Laurel area a rail center for the entire Northern Plains. A principal in the Northern Pacific Railroad, Frederick Billings, would be instrumental in bringing sufficient capital into the area to invest in banks and businesses in the central part of the valley. Additional laws passed to encourage irrigation, as well as expansion of the Homestead Act in the early 1900s, encouraged the first major U.S. Bureau of Reclamation (USBOR) irrigation project at Huntley, east of Billings, and other local irrigation projects near Billings and Laurel, as well as the first sugar refinery in 1906. The infusion of capital, the conjunction of the railroads, the growth of irrigated agriculture, and the emergence of industrial activity in the Billings area would cause the town to expand in population from about 7,000 in 1907 to over 12,000 by the following year (Lang 1995). Even if Billings had not continued to grow through the 20th century, its size in 1908 would have still made it the largest community along the Yellowstone in 2010.

Down river, a second USBOR project, the Lower Yellowstone Project, created another center of agriculture, causing the formation of the town of Sidney and a new county to be carved out of Dawson County by 1914. A second expansion of agriculture occurred in the 1920s when Sidney became the location of a second sugar refinery, making sugar beets an economic mainstay of the valley and irrigation a focal point for valley agriculture (Malone et al. 1991).

The Yellowstone River Valley grew rapidly for other reasons. A fourth railroad (the Milwaukee Road in 1907) ran along a portion of the lower valley and established a division point at Miles City; encouraging growth to the early settlement there based on cattle ranching. Coal mining at the periphery of the Yellowstone region also fed the economy at several points along the valley from the early 1900s into the 1920s. And after 1940, oil development brought further wealth and population to the Yellowstone Valley. Eventually, three oil refineries would be built in the Billings area.

Although growth along the Yellowstone was slowed by the Great Depression and World War II; by 1950 the emergent economy of the region had already developed the vast majority of agricultural lands still being irrigated today. Most of the transportation infrastructure—local roads and railroad—was also in place. The only major additional transportation system developed after 1950 was the Interstate Highway System, specifically Interstate-90/94, present in the Yellowstone corridor (Van West 1995).

Other economic sectors continued to grow and change and can be indirectly seen in the growth of urban areas and rural subdivisions. For instance, the region that includes the Billings urban area floodplain grew 420 percent in footprint between 1950 and 2011. That included housing, industrial areas, and other urban features. Billings became a commercial, shopping, medical, transportation, and industrial center for a wide area of the Northern Plains, and that trend accelerated after 1950.

Another noticeable change was the influx of people attracted to the Upper Yellowstone for its scenery, fishing, and general outdoor amenities. Park County, including the Livingston area, increased its footprint of exurban developments by nearly 2,000 percent between 1950 and 2011. This has altered the nature of economic activity, not only in Park County, but downstream as far as Billings (Thomas and Swindell 2013).

3.0 STUDY AREA AND STUDY REACHES

3.1 Study Area Stationing, Regions and Reaches

The Yellowstone River CEA project reach extends over 565 river miles from Gardiner, Montana to the Missouri River confluence. Evaluating a river system of this size requires segmentation of the corridor in order to meaningfully evaluate conditions and trends. One of the first efforts for the CEA study was a reconnaissance evaluation of the project area, which was completed in 2004 (AGI and DTM 2004). This original reconnaissance was performed for all counties except Park County in the upper river; the Park County portion of the area was later added to the study.

The 2004 reconnaissance study broke the river into regions to reflect downstream changes in broad-scale physiography. Within those regions, the river was further segmented into reaches that could be grouped in terms of basic form, allowing comparisons of cause-and-effect relationships, both spatially and temporally, for a given reach type. The reconnaissance report contains a summary of regional geologic history, regional trends in river morphology such as slope, valley width and sinuosity, and a discussion of primary human influences that appear to be influencing river processes (AGI and DTM 2004).

3.1.1 Regional Geomorphic Zones

Between Gardiner and the Yellowstone River/Missouri River confluence, the physiography of the Yellowstone River and its tributaries transitions from steep, confined mountainous areas to plains conditions. This physiographic transition correlates to a downstream transition from a coldwater salmonid fishery to a warmwater fishery. To ensure that the comparison of reaches in the cumulative effects analysis is applied to reaches of similar baseline conditions, the corridor was subdivided into five regional zones (Table 3-1, Figure 3-1), and then further subdivided into 88 individual river reaches. The regional zones are generally based on the dominant fish species and include a coldwater headwaters zones, a transition zone, and two warmwater plains zones. Various studies have placed the downstream end of the coldwater headwaters zone in several places, including Big Timber (Montana DNRC 1976), Reed Point (Zelt et al. 1999), or Columbus (Silverman and Tomlinson 1984). The primary change to warmwater species has been identified starting at the confluence of the Clarks Fork River (Montana DNRC 1976) near Laurel. The downstream end of the transition zone is consistently placed at the Bighorn River confluence. Below the Bighorn, the river is a plains river with a warmwater fishery. The downstream changes in dominant fish species are reflected in progressive changes in landscape geomorphology. The upper reaches are steeper and have a coarser bed substrate. Channel slope and substrate size decrease in the downstream direction.

Table 3-1
Major Geographic Regions of Yellowstone River CEA Study

Region	River Miles	Length (miles)	Location	Reaches
Region PC	479-564	85	Gardiner to Springdale	PC1 – PC21
Region A	384-479	95	Springdale to Clarks Fork River	A1 – A18
Region B	298-384	86	Clarks Fork River to Bighorn River	B1 – B12
Region C	149-298	149	Bighorn River to Powder River	C1 – C21
Region D	0-149	149	Powder River to Missouri River	D1 – D16

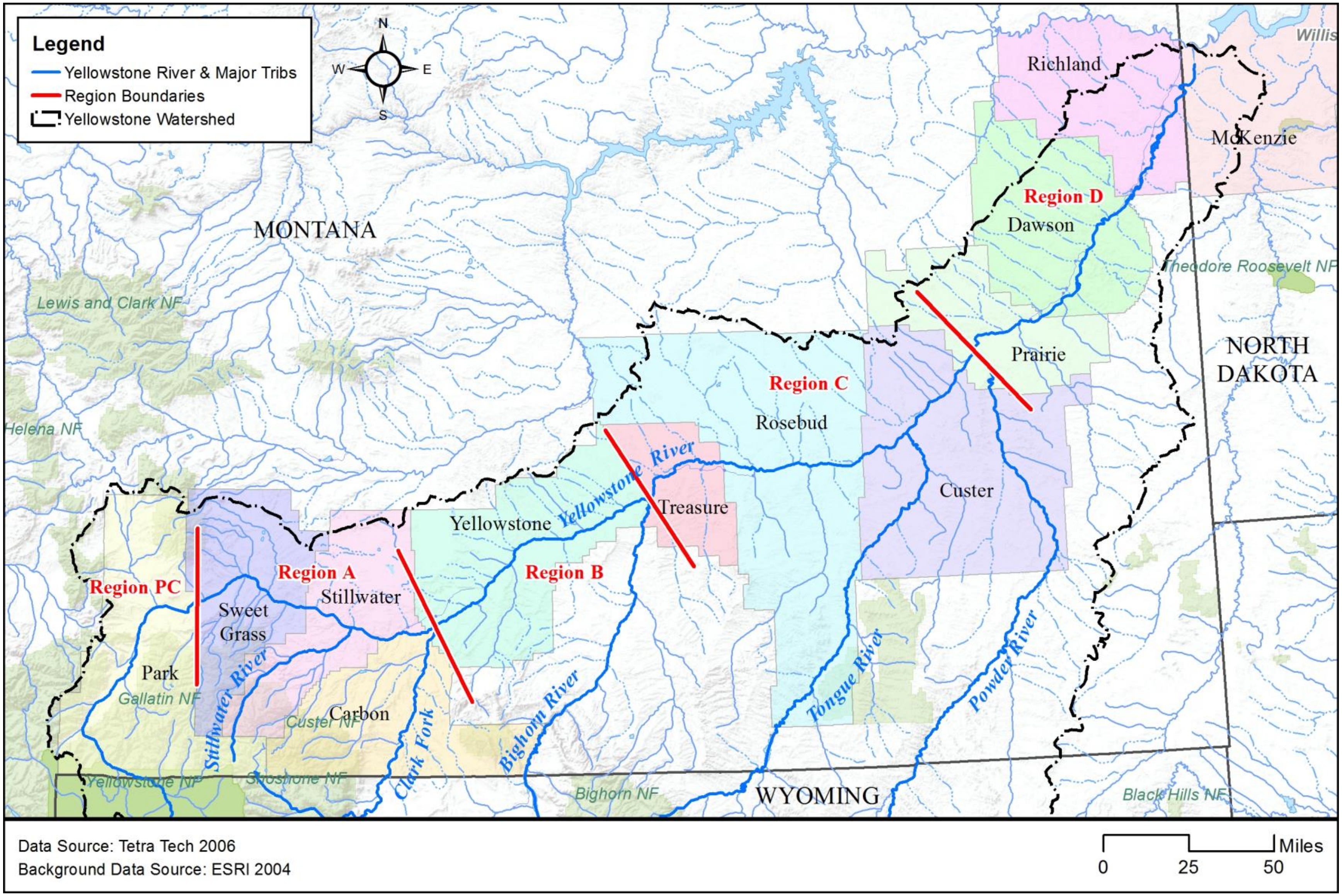

Figure 3-1 **Region boundaries within the study area**

The uppermost of the five primary geomorphic regions, Region PC (Park County) extends from Gardiner to Springdale. The next region, Region A, extends from Springdale to the Clarks Fork River confluence at Laurel. The break at Laurel was selected based on changes in dominant fish species, a reduction in valley confinement and channel slope, and the hydrologic and sediment influences of the Clarks Fork. From the Clarks Fork, Region B encompasses the entire transition zone, extending downstream to the Bighorn River. The warmwater section was divided into two regions: the upper one, Region C, extends from the Bighorn River to the Powder River; and the lower one, Region D, extends from the Powder River to the Missouri River. The break at the Powder River is based on the relatively large, fine-grained sediment load delivered by the Powder River to the Yellowstone, and the associated probable effects on stream morphology and fisheries habitat. The major characteristics of each region are described below.

Region PC: In Park County, the Yellowstone River flows through major geologic controls from Gardiner to Point of Rocks, where channel migration rates are minimal and the riparian corridor is very narrow. Below Emigrant, the channel is more dynamic, although locally confined by both low and high terraces. Spring creeks in the Paradise Valley occur on both sides of the main channel. This area is prone to major sediment loading from terrace erosion during flood events. Through Livingston, the river is confined by extensive armor and dikes. Downstream of Livingston near Mission Creek, wooded islands and open bars are common. There are 21 reaches over 85 river miles in Park County. All of the reaches are at least partially confined, indicating that bedrock and terraces strongly influence the river corridor. The channel substrate consists primarily of gravel, cobble and boulders, and the average channel slope is 11 feet per mile (0.2 percent). These conditions provide high quality habitat and spawning grounds for salmonids. In Region PC, the Yellowstone River supports a coldwater salmonid fishery, including cutthroat trout, rainbow trout, brown trout, and mountain whitefish. The reach is classified as a “blue ribbon” trout stream (Montana DNRC 1976).

Region A: From Springdale to the Clarks Fork River confluence near Laurel, the river is 95 miles long and is divided into 18 reaches. These reaches are typically anabranching (supporting long side channels separated from the main channel by wooded islands), as well as braided (supporting split-flow channels around open gravel bars). Similar to Park County, the reaches are typically partially confined, indicating that a bedrock valley wall or an alluvial terrace commonly affects one bank of the river. The low terrace commonly follows the channel edge, and a few exposures of high terrace locally bound the modern river corridor. Similar to Region PC, this section of river supports a coldwater salmonid fishery. Sweet Grass, Carbon, and Stillwater Counties are located in Region A.

Region B: Between the Clarks Fork River confluence and the Bighorn River confluence, the river is divided into 12 reaches over 86 river miles. Reach types are variable, ranging from straight to braided. Similar to Region A, bedrock valley wall controls are intermittent. Both low and high terrace features locally form the channel bankline. Region B includes the area around Billings, which is densely armored and highly impacted. Between the Clarks Fork confluence and the Bighorn River confluence, the river is within a biological transition, with both cold and warmwater fish species present. Silverman and Tomlinson (1984) identify 20 fish species from eight families that inhabit the transition zone. Water temperatures gradually increase in the downstream direction. Within this reach, the average gradient is 8 feet per mile (0.15 percent) and the channel substrate includes more fine sediment. The transition zone lies entirely within Yellowstone County.

Region C: Between the Bighorn River and the Powder River, the Yellowstone River is a low-gradient system that supports a wide range of reach types. Region C is divided into 21 reaches, ranging from unconfined, multi-thread channels in the Mission and Hammond Valleys to highly-confined areas downstream of Miles City. Region C marks the first river section that is impacted by hydrologic alterations associated with Yellowtail Dam operations on the Bighorn River. Downstream of the Bighorn River confluence, a plains warmwater fishery is supported, which is characterized by a diverse variety of non-salmonid, warmwater species. In this section, which is approximately 150 miles long, the Yellowstone is a prairie river. This aquatic ecosystem includes carp, goldeye, burbot, stonecat, sauger, walleye, channel catfish, paddlefish, and shovelnose sturgeon (Montana DNRC 1976, 1977; Schneider 1985). The channel slope is relatively consistent in Region C at approximately 3 feet per mile (0.06 percent). Backwater areas are heavily silted, even though the channel bed consists of cobble and gravel. The Region C plains zone includes Treasure, Rosebud, and Custer County.

Region D: Below the Powder River confluence, the river is 149 miles long and is divided into 16 reaches. The uppermost segments of this region, from the Powder River to Fallon, are closely confined by bedrock valley walls. Downstream of Fallon, confinement is reduced, and broad islands are common. Region D supports a warmwater fishery and tends to be relatively fine-grained and low-gradient. Within Region D, the Yellowstone is a prairie river somewhat similar to Region C in terms of fisheries. These two zones collectively support 46 species of fish from 12 families (Silverman and Tomlinson 1984). However, the river gradient within Region D drops in the downstream direction from 3 feet per mile near the Powder River to approximately 1 foot per mile (0.02 percent) downstream of Sidney. In Region D, low channel gradients are accompanied by relatively high turbidity and multiple thread channel segments. The average valley bottom width of Region D is over 3 miles, whereas that of Region C is approximately 2 miles. The geomorphic environments associated with quality fisheries habitat in Region D include side channels, chutes, and backwater areas. Climax riparian plant communities in the plains zone typically consist of grassland species, including blue grama and western wheatgrass. Near the mouth of the river, rainfall increases and forests of green ash and bur oak form the climax community (Silverman and Tomlinson 1984). Region D includes Prairie, Dawson, Wibaux, Richland, and McKenzie Counties.

3.1.2 Reach Delineation and Classification

The 2004 Yellowstone River reach delineation and classification had the following objectives (AGI and DTM 2004):

- Segment the project area into manageable lengths (reaches) for the CEA analysis, as well as for future efforts such as research, restoration implementation, and monitoring.
- Characterize each reach.
- Develop a classification system that can be used to describe all reaches.
- Assign reach types to every reach.

The goal was to develop a simple classification system that would help differentiate reaches in terms of their natural propensities to support various types of habitats and experience given rates of change. The primary information used included 2001 color infra-red air photos, geologic mapping, a physical features inventory, soils maps, floodplain delineations, and some vegetation mapping. The parameters used in the reach classification are described in the sections below.

3.1.2.1 Stream Pattern

Stream pattern is a major component of remote channel classification, largely because the channel pattern is readily discernible on aerial photographs. Also, stream pattern provides a good indicator of the relative dynamics of a stream; that is, whether the stream is prone to rapid change (e.g., braided) or slow change (e.g., straight and single thread). The following pattern categories were utilized in the classification (Brice 1975):

- Meandering—A dominant single thread channel, with a sinuosity typically in excess of 1.2
- Braiding—Extensive unvegetated mid-channel bars
- Anabranching—Well-vegetated islands that are typically over 3 times wider than the active channel

3.1.2.2 Confinement

The materials that make up the bed and banks of stream profoundly influence its form and behavior (Kondolf et al. 2003). On the Yellowstone River, whether the river is flowing in the middle of the valley or against the edge affects channel migration rates and patterns, riparian conditions, and in-stream habitat. The following descriptors have been applied to each reach, based on a qualitative assessment of aerial photographs:

- Unconfined—Reaches where the river flows within the core of the valley and does not run against the valley wall. These reach types are commonly located where the river crosses from one side of the valley to another, and they are typically very dynamic.
- Partially Confined—Partially confined reaches are those where the channel flows along the valley wall for at least some of its length. These reaches are common and tend to show moderate levels of change through time.
- Confined—Confined reaches are in narrow river valleys where both streambanks are dominated by bedrock or terraces. This occurs most prominently between Miles City and Fallon (RM 176-125) where sandstones of the Fort Union Formation tightly confine the river valley and in the top four reaches of Park County where the river is confined by bedrock and glacial terraces. These reaches tend to show very slow rates of channel movement and support only a narrow fringe of riparian vegetation.

3.1.2.3 Assigned Classifications

The river was divided into 88 reaches between Gardiner and the mouth based on classifications of confinement and pattern. Table 3-2 lists the classifications assigned to the reaches. The first column of the table also shows the “General Channel Type,” which is related to the reach types used in some of the data analyses.

Individual reach locations are displayed in Figure 3-2 through Figure 3-6. The reach names refer first to region and then to a sequential number from upstream to downstream within that region (e.g., Region A contains reaches A1 through A18, with Reach A1 at the upper end of the region). Each region contains between 12 (Region C) and 21 (Region PC) individually classified reaches. Reach lengths range from about 3 to 12 river miles. Table 3-3 contains a list of reach locations and classifications. For a more detailed discussion of the reach classification, see the 2004 Reconnaissance Report (AGI and DTM 2004).

Table 3-2
Summary Parameters for Reach Classification

General Channel Type	Detailed Channel Type	Detailed Channel Type Reference	Number of Reaches	Natural Confinement	Gravel Bar Frequency	Side Channel Frequency
Anabranching	Unconfined anabranching	UA	12	Low	Moderate	High
	Partially confined anabranching	PCA	18	Moderate	Moderate	High
Braided	Unconfined braided	UB	6	Low	High	High
	Partially confined braided	PCB	13	Moderate	High	High
Meandering	Partially confined meandering	PCM	4	Moderate	Low/Moderate	Moderate
	Partially confined meandering/islands	PCM/I	11	Moderate	Low/Moderate	Moderate
Straight/ Confined	Partially confined straight	PCS	11	Moderate	Low/Moderate	Low
	Confined straight	CS	5	High	Low	Low
	Confined meandering	CM	7	High	Low	Low
Straight/ Unconfined	Unconfined straight/islands	US/I	1	Low	Low/Moderate	Moderate
Source: AGI and DTM 2004						

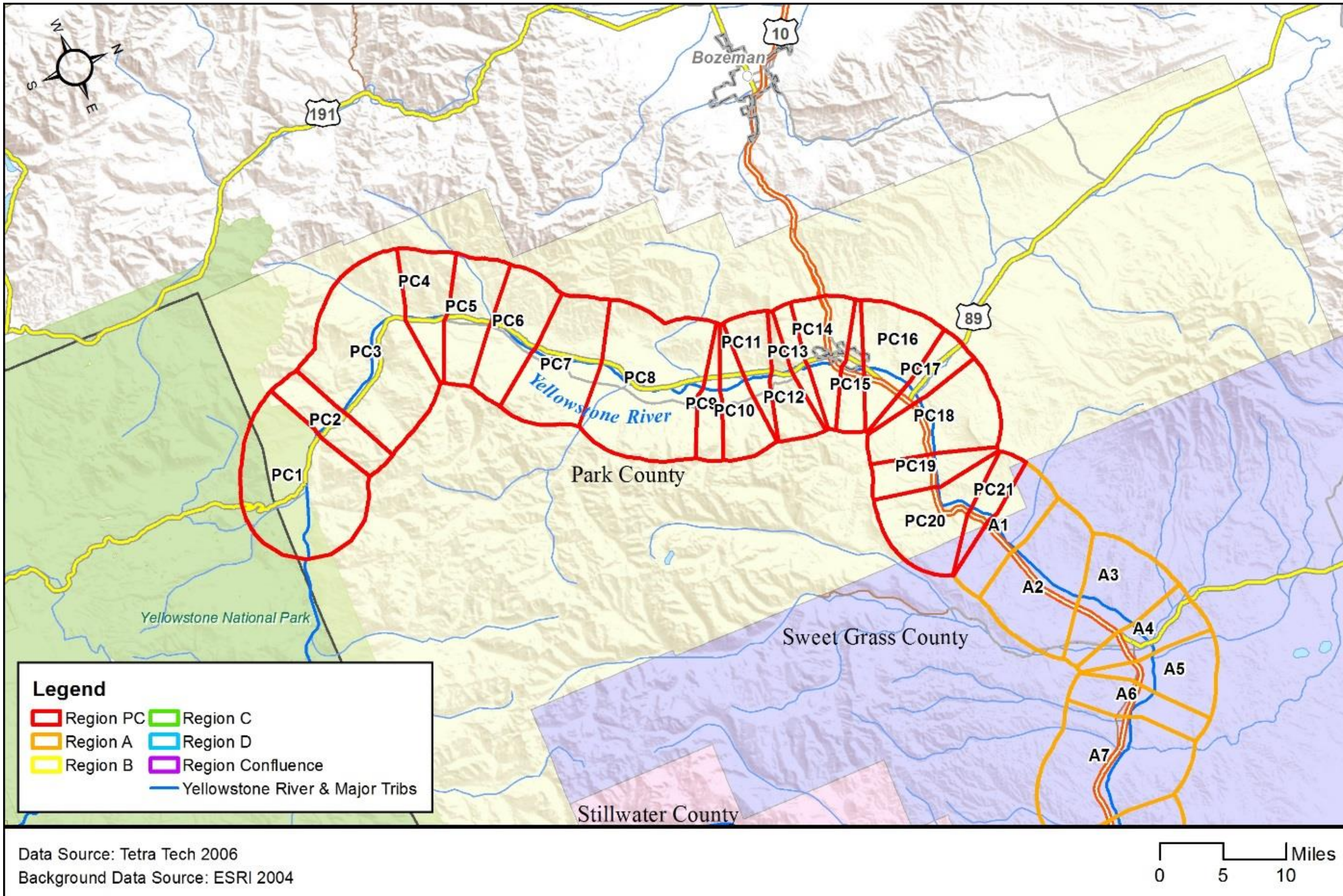

Figure 3-2 Reaches within Region PC

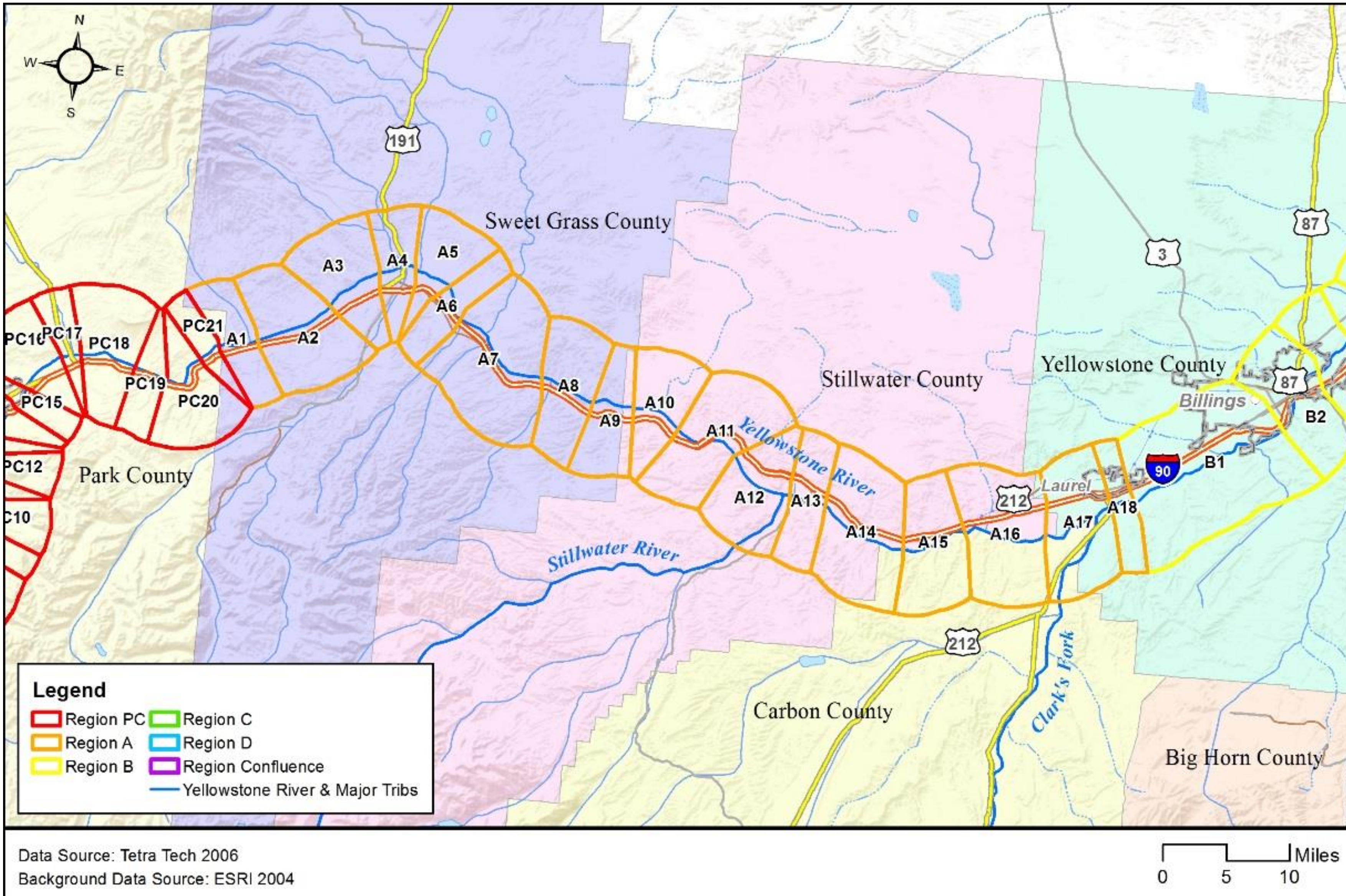

Figure 3-3 Reaches within Region A

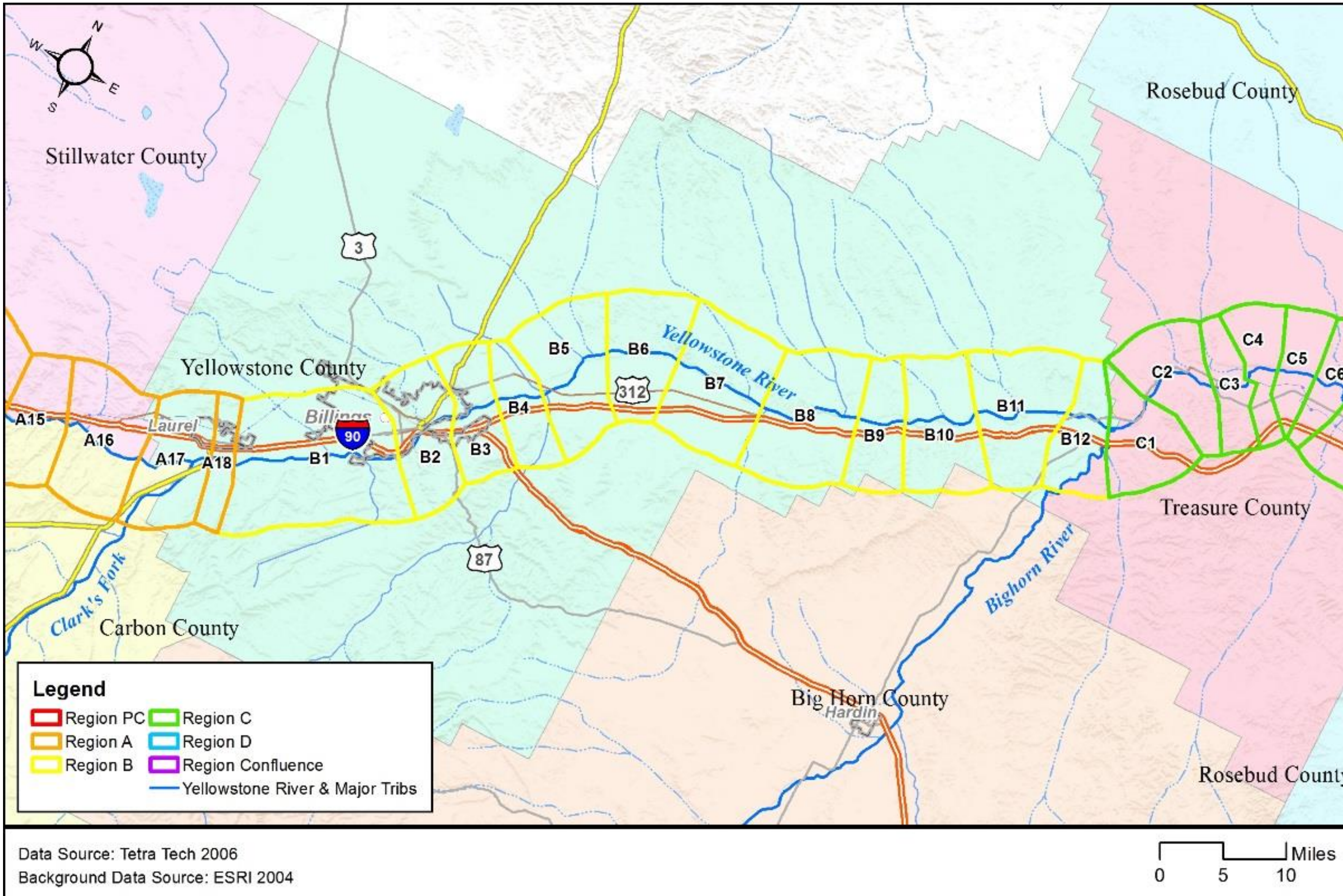

Figure 3-4 Reaches within Region B

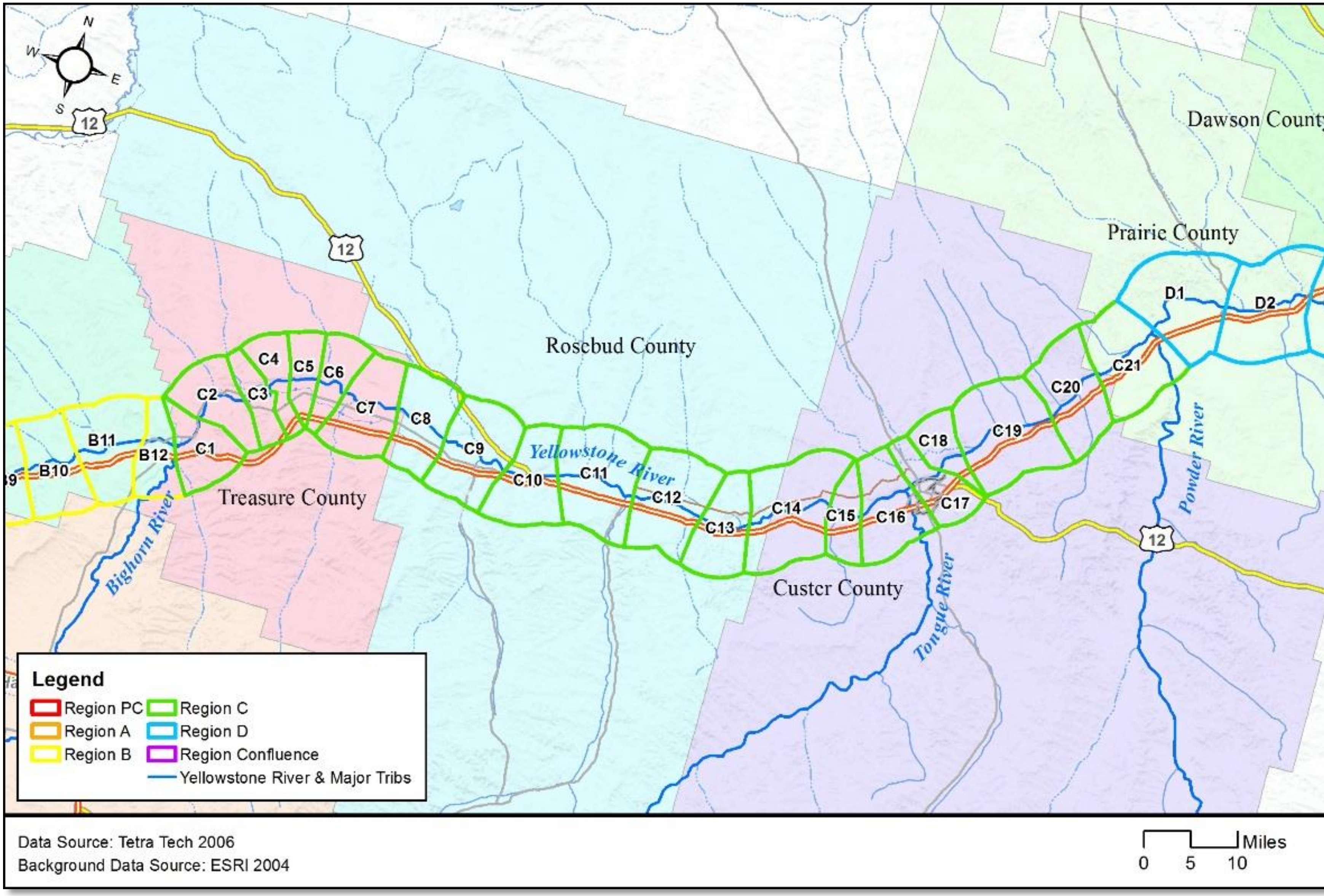

Figure 3-5 Reaches within Region C

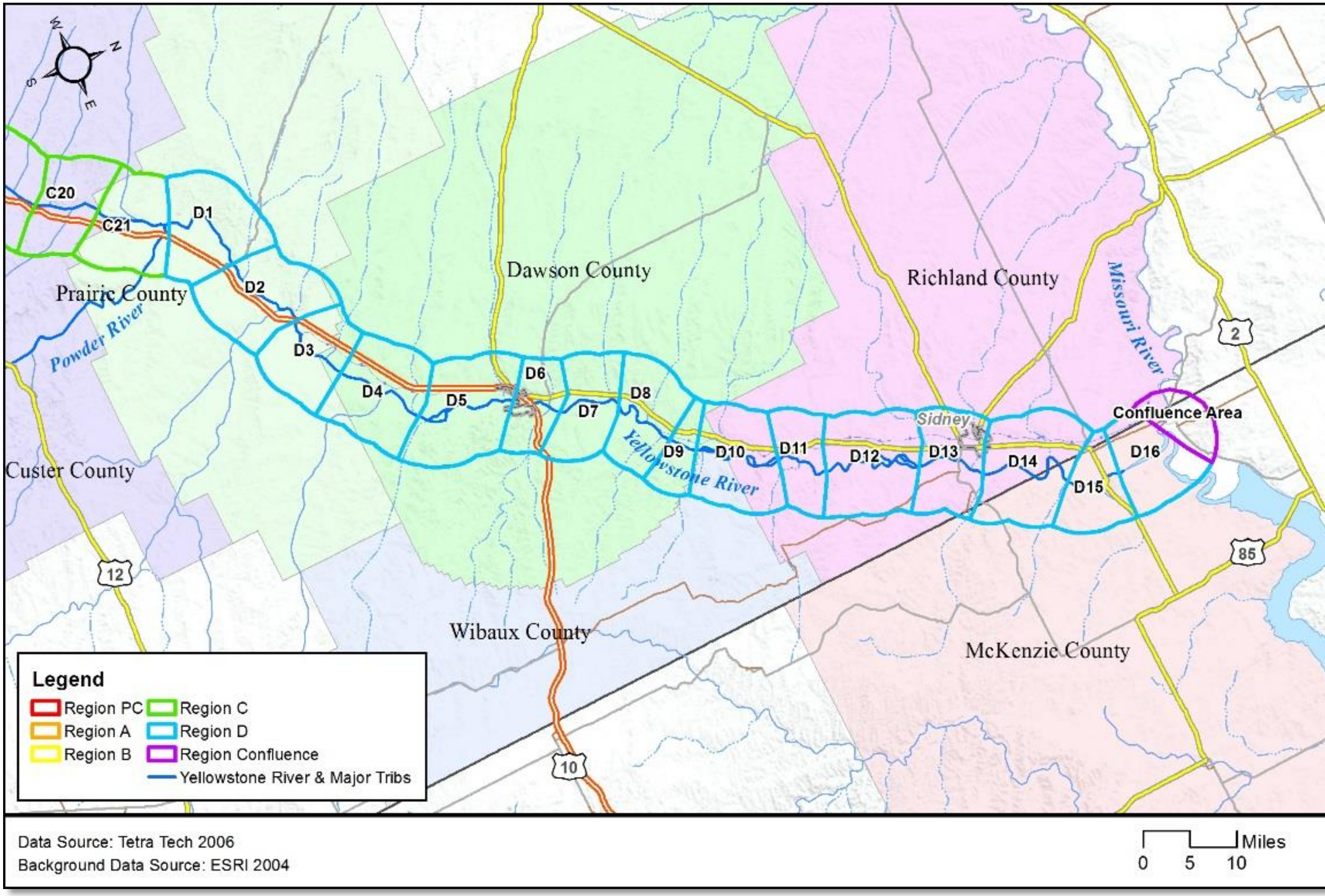

Figure 3-6 Reaches within Region D

Table 3-3
Reach Locations and Classifications

Reach Identification	Length (mi)	County	Channel Type Reference	General Location
PC1	3.80	Park	CS	Gardiner to Little Trail Creek
PC2	3.00	Park	CM	Devil's Slide area
PC3	10.40	Park	CS	Corwin Springs to Carbella; Yankee Jim Canyon
PC4	3.60	Park	CM	Carbella to Hwy 89 Bridge
PC5	3.80	Park	PCA	Hwy 89 Br. to Big Creek
PC6	4.40	Park	CM	Big Creek to Six Mile Creek
PC7	6.00	Park	PCA	Six Mile Cr to Grey Owl
PC8	12.70	Park	CM	Grey Owl to just below Mallard's Rest
PC9	1.70	Park	PCA	To Pine Creek
PC10	3.60	Park	PCM	To downstream of Deep Creek; Weeping wall, Jumping Rainbow; onset of spring creeks
PC11	2.30	Park	PCA	To near Suce Creek, Wineglass Mountain to west
PC12	2.00	Park	PCM	To Carters Bridge
PC13	1.70	Park	PCB	Through canyon upstream of Livingston
PC14	3.30	Park	PCA	To Livingston
PC15	1.80	Park	PCS	To Mayor's Landing
PC16	4.30	Park	PCA	To just upstream of Hwy 89 bridge
PC17	2.00	Park	PCB	Through Hwy 89 bridge crossing to Shields River
PC18	5.30	Park	UA	To below Mission Creek
PC19	2.90	Park	CS	To near Locke Creek
PC20	4.40	Park	PCS	
PC21	2.20	Park	PCA	To Springdale
A1	3.40	Sweet Grass	PCB	Springdale
A2	6.90	Sweet Grass	UB	Grey Bear fishing access
A3	5.50	Sweet Grass	PCB	Upstream of Big Timber
A4	3.30	Sweet Grass	UB	To Boulder River confluence
A5	3.30	Sweet Grass	UB	
A6	3.10	Sweet Grass	PCS	
A7	9.70	Sweet Grass	PCB	Greycliff
A8	5.10	Sweet Grass	PCB	R/R
A9	3.80	Sweet Grass, Stillwater	UA	To Reed Point
A10	4.40	Stillwater	PCS	
A11	7.00	Stillwater	PCB	I-90 Bridge crossing
A12	6.00	Stillwater	PCB	To Stillwater confluence
A13	3.60	Stillwater	PCA	Columbus
A14	7.80	Stillwater	PCA	

Reach Identification	Length (mi)	County	Channel Type Reference	General Location
A15	5.90	Stillwater, Carbon	PCB	Follows Stillwater/Carbon County line
A16	7.60	Stillwater, Carbon	PCA	Park City
A17	6.40	Yellowstone, Carbon	UA	To Laurel
A18	2.50	Yellowstone	UA	To Clarks Fork River
B1	15.20	Yellowstone	UB	
B2	6.10	Yellowstone	PCB	Billings
B3	4.30	Yellowstone	UB	
B4	3.90	Yellowstone	PCS	
B5	7.30	Yellowstone	UA	Huntley
B6	6.10	Yellowstone	PCB	
B7	8.80	Yellowstone	UB	
B8	9.10	Yellowstone	PCA	Pompey's Pillar
B9	4.70	Yellowstone	UA	
B10	7.20	Yellowstone	PCM	
B11	8.10	Yellowstone	PCA	To Custer Bridge
B12	4.60	Yellowstone	UA	To Bighorn River confluence
C1	5.80	Treasure	UA	
C2	5.50	Treasure	PCB	To Myers Bridge
C3	4.80	Treasure	UA	To Yellowstone Diversion
C4	3.80	Treasure	PCB	Below Yellowstone Diversion
C5	3.20	Treasure	PCS	Hysham
C6	5.60	Treasure	UA	Mission Valley
C7	9.10	Treasure	UA	Mission Valley
C8	6.50	Treasure, Rosebud	PCS	Rosebud/Treasure County Line
C9	10.70	Rosebud	UA	Hammond Valley
C10	6.80	Rosebud	PCM	Forsyth
C11	11.30	Rosebud	PCM/I	To Cartersville Bridge
C12	10.20	Rosebud	PCM/I	Rosebud
C13	6.70	Rosebud	PCM/I	
C14	12.20	Rosebud, Custer	PCM/I	
C15	3.60	Custer	PCS	
C16	7.30	Custer	PCM/I	to Miles City
C17	4.50	Custer	PCS	Miles City; Tongue River
C18	3.20	Custer	PCS	
C19	11.10	Custer	CS	
C20	7.50	Custer, Prairie	CS	
C21	9.50	Custer, Prairie	CM	To Powder River
D1	12.20	Prairie	CM	To Terry Bridge
D2	10.50	Prairie	CM	To Fallon, I-90 Bridge
D3	8.40	Prairie, Dawson	PCS	Into Dawson County
D4	11.00	Dawson	PCM/I	
D5	12.50	Dawson	PCA	To Glendive
D6	5.60	Dawson	PCM/I	Glendive

Reach Identification	Length (mi)	County	Channel Type Reference	General Location
D7	7.60	Dawson	PCA	
D8	10.30	Dawson	PCA	To Intake
D9	3.30	Dawson	PCM/I	Downstream of Intake
D10	11.50	Dawson, Wibaux, Richland	PCA	
D11	6.40	Richland	PCA	Elk Island
D12	13.60	Richland	PCA	
D13	8.50	Richland	PCM/I	
D14	14.30	Richland, McKenzie	PCM/I	Into McKenzie County, North Dakota
D15	6.00	McKenzie	PCM/I	
D16	7.50	McKenzie	US/I	To Missouri River confluence

3.1.3 River Mile and Valley Mile Referencing

Many of the spatial references in this document refer to river mile or valley mile. The river mile stationing is based on a digitized centerline from 2001 aerial imagery. Valley miles are defined by a digitized valley line that follows the main river corridor axis. The river mile distance from Gardiner to the Missouri river is 5654 miles. The valley distance between those points is 466 miles. To put the data into a spatial context, lists the reach, valley mile, and river mile locations of major towns, confluences, and counties are listed in Table 3-4 through Table 3-6.

Table 3-4
Reach Locations of Major Towns

Town	River Mile	Valley Mile	Reach
Gardiner	564	466	PC1
Livingston	501	413	PC15
Big Timber	461	377	A4
Reed Point	434	353	A10
Columbus	416	337	A13
Laurel	386	311	A18
Billings	365	293	B2
Hysham	277	220	C5
Forsyth	239	193	C10
Miles City	185	150	C17
Terry	139	111	D1
Glendive	94	171	D6
Intake	73	56	D8
Sidney	29	22	D13
Fairview	12	10	D15

Table 3-5
Reach Locations of Major Confluences

Confluence	River Mile	Valley Mile	Reach
Mill Creek	526	431	PC8
Shields River	494	406.5	PC17
Boulder River	460	376	A4
Stillwater River	417.5	338.5	A12
Clarks Fork River	383.5	309	A18
Pryor Creek	354	283	B5
Bighorn River	298	236	B12
Tongue River	185	150	C17
Powder River	150	119	C21

Table 3-6
Reach Locations of Major Counties

County	Reaches
Park	PC1-PC21
Sweet Grass	A1-A9
Stillwater	A10-A16
Carbon	A15-A16
Yellowstone	A17-B12
Treasure	C1-C7
Rosebud	C8-C13
Custer	C14-C20
Prairie	C21-D3
Dawson	D4-D9
Richland	D10-D14
McKenzie	D15-D16

3.2 CEA Database and Reach Narrative Development

Many of the datasets developed for the Cumulative Effects Assessment (CEA) were summarized by reach. This allowed the compilation of diverse datasets related to hydrology, hydraulics, geomorphology, riparian, wetlands, avian, and fisheries at a consistent and manageable scale for interpretation of cause-and-effect relationships. Packaging and interpreting the interdisciplinary results on a reach scale was an effective means of providing information to other users and decision makers in the corridor. To achieve that, the reach-based results for each topic were collected in a relational database. A series of queries and reports were generated to create an output format that summarizes the project data in a consistent format for every reach. These reports are collectively referred to as the “Reach Narratives.” They can be rapidly generated out of the database to compile summary information for each reach. Additional narrative and graphics (maps and graphs) are provided to help users interpret the data.

Because of the amount of information generated and compiled for the study, the full Reach Narrative reports tend to be in excess of 15 pages in length each. With 88 reaches, this amounts to over 1,300 pages of reach narratives. These full narratives contain detailed information from the analyses performed in support of the CEA and provide the user with descriptions of the datasets and potential applications. The narratives also include potential applications of specific Yellowstone River Recommended Practices (YRRP).

A condensed narrative was generated for each reach that includes a reach description, a sheet with key CEA-related parameter values from the database, a location map showing river miles, bank armor, and floodplain dikes, and a map showing the modeled 5-year floodplain boundary (modern flow conditions) and the Channel Migration Zone (CMZ) boundary. The narrative summary describes the reach location and selected reach data and presents recommended practices for the reach. A sample condensed narrative is shown on Figure 3-7 through Figure 3-10 for Reach C9 above Forsyth.

The CEA database is in Microsoft Access format that can be updated as more information becomes available. Updating the database will automatically update the narrative reports.

Yellowstone River Reach Narratives

Reach C9

County	Rosebud	**Upstream River Mile**	253.8
Classification	UA: Unconfined anabranching	**Downstream River Mile**	243.1
General Location	Hammond Valley	**Length**	10.70 mi (17.22 km)

Narrative Summary

Reach C9 is 10.7 miles long and is located in the Hammond Valley upstream of Forsyth. The Hammond Valley is an unusually wide segment of the Yellowstone River corridor, similar to the Mission Valley near Hysham. These two valleys owe their shape to the presence of the Bearpaw Shale in the valley wall, which is relatively erodible and prone to mass failure. Because the Mission and Hammond Valleys are so wide, the river has developed a complex series of channels and an expansive riparian forest. These reaches are especially rich in terms of aquatic and riparian habitat extent, diversity, and geomorphic complexity. Reach C9 is an Unconfined Anabranching (UA) reach type, which is typically the most complex and dynamic reach type on the river.

Flow alterations in Reach C9 have been driven primarily by changes in flows on the Bighorn River and water use for irrigation. The 2-year discharge, which is an important flow statistic because it approximately defines the channel capacity, has dropped by 14,400 cfs, or 23.5%, due to flow alterations on the river. That reduction in flow has been accompanied by a reduction in the bankfull channel area, or channel size, by 209 acres since 1950.

There is over 10,000 feet of rock riprap in Reach C9, as well as 1,100 feet of flow deflectors. This reach experienced severe bank erosion during the 2011 flood when some banks migrated several hundred feet. In response to that erosion, several thousand feet of bank armor were constructed after 2001, mostly on the south side of the river. This riprap represents both new projects and extensions on older projects. Some flow deflectors in the reach were flanked during the flood and now sit in the middle of the river. Other impacts in Reach C9 include almost four miles of side channel that have been blocked by dikes. This loss is due to the blockage of one very long side channel on the north side of the corridor that was clearly active in 1950, but by 1976 was plugged on its upper end.

The combination of bank armoring and reduced energy due to flow alterations has resulted in a reduced floodplain turnover rate in Reach C9 from 22.2 acres per year to 12.9 acres per year. The area of open bar habitat mapped under low flow conditions dropped by almost 100 acres since 1950, reflecting riparian expansion into the channel, reduced sediment recruitment from banks, and reduced sediment loading from the Bighorn River.

Over 40% of the land area that was historically inundated by a 5-year flood now remains dry during that frequency event. Most of these isolated areas currently typically flood irrigated fields, some of which were riparian forest in the 1950s. The vast majority of irrigated land in Reach C9 is under flood irrigation (3,900 acres) while 515 acres are under pivot. In the upstream end of the reach, pivots on either side of the river extend into the Channel Migration Zone. About 6% of the total CMZ has been restricted by physical features.

There are several animal handling facilities in Reach C9 that are adjacent to the main river channel or smaller side channels, tributaries, or swales. These are located at RM 252L (side channel), RM 248L (tributary), and RM 245R (main channel).

Reach C9 was sampled as part of the avian study. A total of 73 bird species were identified in the reach. Five bird species identified by the Montana Natural Heritage Program as potential species of concern (PSOC) were found, the Black and White Warbler, Dickcissel, Plumbeous Vireo, Ovenbird, and Chimney Swift. Three Species of Concern (SOC) were identified, the Black-billed Cuckoo, Bobolink, and Red-headed Woodpecker. With the expansion of agriculture in the reach, the extent of forest at low risk of cowbird parasitism dropped from 108 acres per valley mile in 1950 to 64 acres per valley mile in 2001.

Reach C9 has 74 acres of mapped Russian olive, which appears to be concentrated on the banks of isolated side channels and sloughs, but also distributed through cottonwood forest in the downstream portion of the reach.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 24%. 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 4,720 cfs to 3,020 cfs with human development, a reduction of 36%. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,150 cfs under unregulated conditions to 3,320cfs under regulated conditions at Reach C10 downstream where the analysis begins, a reduction of 46%.

CEA-related observations in Reach C9 include:
- Reduced floodplain and riparian turnover rates due to flow alterations and bank armoring
- Lost side channel extent due to side channel plugs
- Expansion of Russian olive into abandoned side channels and riparian forest
- 5-year floodplain isolation due to agricultural dikes and flow alterations
- Encroachment of pivot irrigation into Channel Migration Zone
- Increased risk of cowbird parasitism with agricultural expansion

Recommended Practices for Reach C9 include:
- Side channel reactivation at RM 252L
- Nutrient management associated with animal handling facilities at RM 252L, RM 248L, and RM 245R.
- Russian olive removal

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Figure 3-7 Reach Narrative Example, Summary Writeup

Yellowstone River Reach Narratives

Reach C9

The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated from a large dataset that is presented in more detail in the full reach narrative report.

Discharge

	Undev.	Developed	% Change
2 Year (cfs)	61,300	46,900	-23.5%
100 Year (cfs)	121,000	101,000	-16.5%

"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.

Bankfull Channel Area (Ac)

1950	1976	1995	2001	1950-2001
1,562.4	1,537.8	1,336.0	1,353.3	-209.1

Bankful channel area is the total footprint of the river inundated at approx. the 2-year flood.

Physical Features

	2011 Length (ft)	% of Bankline	2001-2011 Change
Rock RipRap	10,283	9.1%	4,427
Concrete Riprap	0	0.0%	0
Flow Deflectors	1,113	1.0%	160
Total	**11,396**	**10.1%**	**4,587**

There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.

Length of Side Channels Blocked (ft)

Pre-1950s	Post-1950s
0	19,348

Numerous side channels have been blocked by small dikes.

Floodplain Turnover

	1950 - 1976	1976 - 2001
Total Acres	576.1	323.2
Acres/Year	22.2	12.9
Acres/Year/Valley Mile	2.9	1.7

1950-2001 In-channel riparian encroachment (negative number indicates retreat): 384.59 acres

The rate of floodplain turnover reflects how many acres of land are eroded by the river. Tunover is associated with the creation of riparian habitat.

Open Bar Area

	Point Bars	Bank Attached	Mid-Channel	Total
Change in Area '50 - '01 (Ac)	-71.6	17	-44.2	-98.8

The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.

Floodplain Isolation

	Acres	% of FP
5 Year	2,045.9	43%
100 Year	300.4	5%

Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.

Restricted Migration Area

Acres	% of CMZ
333.2	6%

Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.

Land Use

	1950	2011
Agricultural Land (Ac)	8,021.5	8,458.6
Ag. Infrastructure (Ac)	88.2	312.0
Exurban (Ac)	0.9	27.5
Urban (Ac)	0.0	0.0
Transportation (Ac)	115.4	104.6

	1950	2011
Flood (Ac)	3,895.4	3,498.6
Sprinkler (Ac)	0.0	0.0
Pivot (Ac)	0.0	515.0

Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.

1950s Riparian Vegetation Converted to a Developed Land Use (ac)

To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.
253.9	0.0	253.9	8.0%

Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.

National Wetlands Inventory

	Acres	Acres per Valley Mi
Riverine	29.2	3.8
Emergent	308.5	40.0
Scrub/Shrub	244.4	31.7

Total Wetland Acres: **582.1**

Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).

Russian Olive (2001) (Appx. 100-yr Floodplain)

Acres	%
74.0	0.7%

Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.

Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)

1950	1976	2001	Change 1950-2011
108.0	65.4	64.1	-44.0

Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.

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Figure 3-8 Reach Narrative Example, Selected Database Output

Yellowstone River Reach Narratives

Reach C9

PHYSICAL FEATURES MAP (2011)

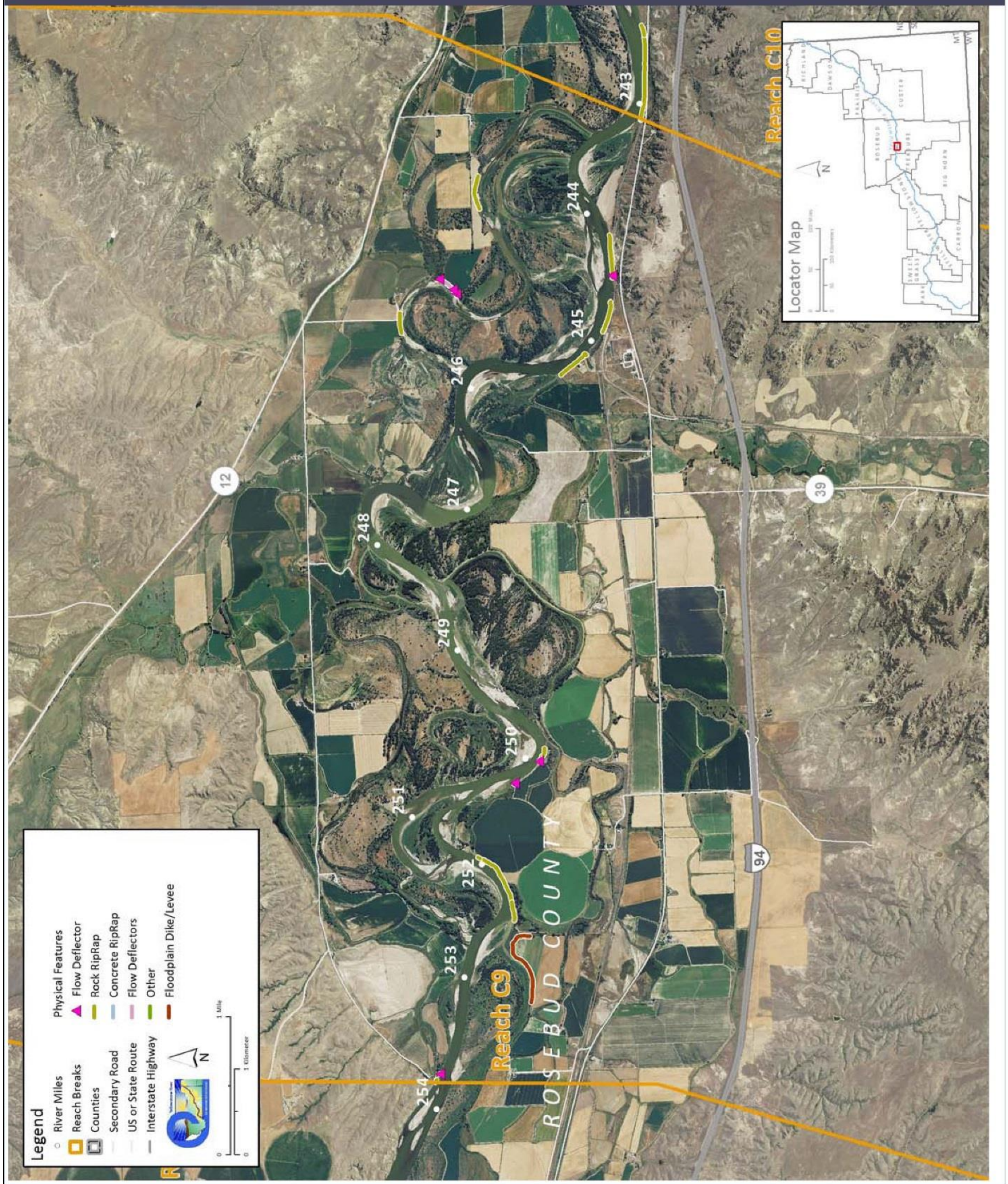

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Figure 3-9 Reach Narrative Example, Location Map showing River Miles and Physical Features

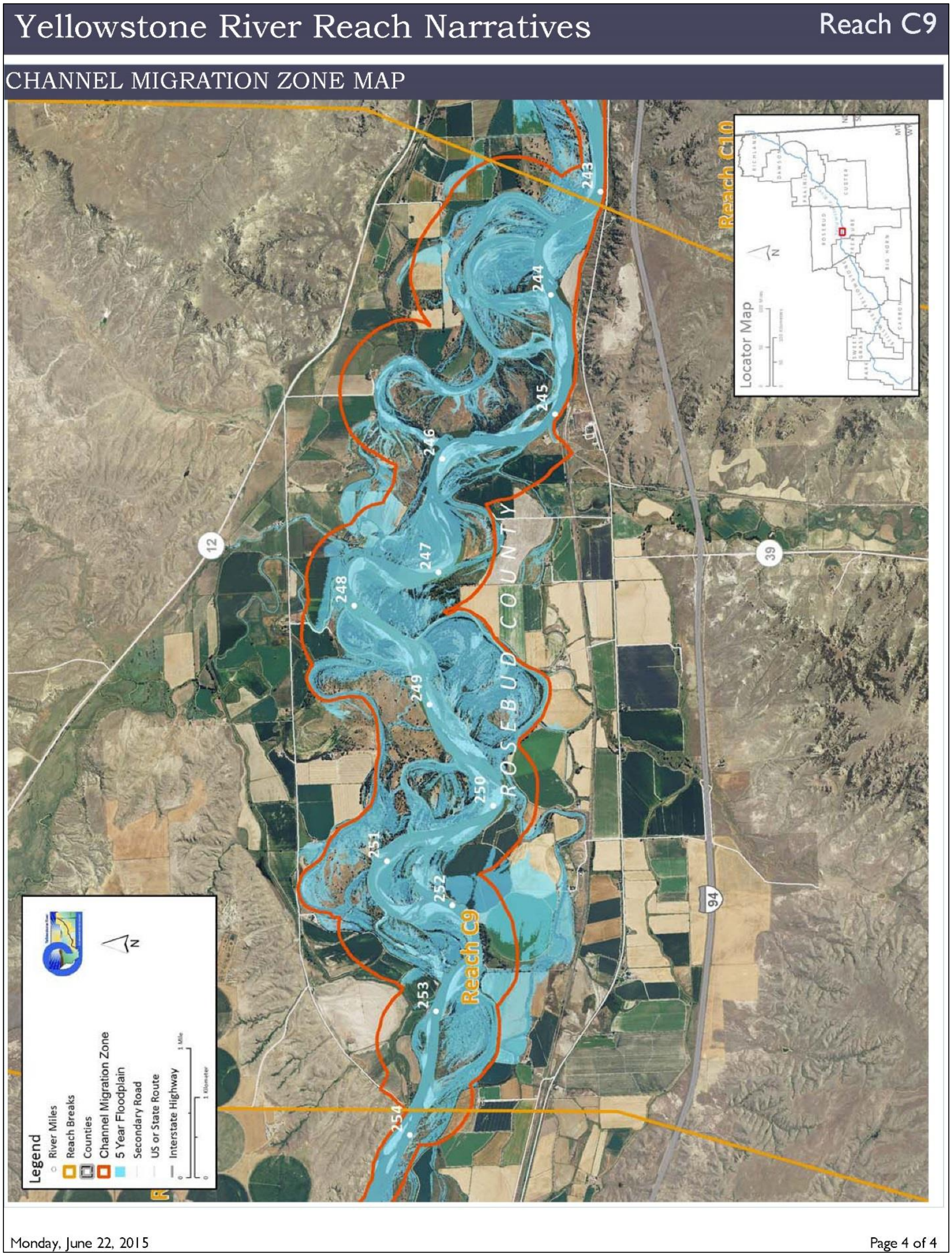


Figure 3-10 Reach Narrative Example, modern 5-Year Floodplain and CMZ boundary

4.0 PRIMARY RIVER ELEMENT CAUSE-AND-EFFECT ANALYSIS

4.1 Primary River Elements

This chapter describes the primary river elements addressed in the Yellowstone River Cumulative Effects Analysis (CEA) study, including analysis of the affected environment and impacts by various stressors. These elements were determined early in the project scoping process (Chapter 1) as being important in defining the character of the river. The primary river elements addressed include:

- Land Use Change
- Hydrology: Hydrograph (i.e., flows)
- Hydraulics: Floodplains
- Geomorphology: Channel Migration and Channel Pattern
- Water Quality
- Biology: Riparian Systems, Wetland Systems, Avian, and Fisheries

The impacts of land uses and other human activities are described in this chapter as major, moderate, and minor effects on the physical and biological elements of the corridor. This is a qualitative ranking. Major effects occur over large portions of the study area or have notably caused changes. Moderate effects can occur over small to large portions of the study area, but have caused less noticeable changes. Minor effects occur only in localized parts of the study area and either there is insufficient data available to document changes or the changes are negligible.

Much of the analysis is supported by spatial datasets compiled in a project Geographic Information System (GIS). Throughout the study, data sets defining the various river elements were created and attributed using the reach and region boundaries (see Chapter 3 Study Area and Reaches) defined in the geomorphic reconnaissance (AGI and DTM 2004) completed at the beginning of the study. By maintaining consistent analysis extents and boundaries across all data sets, it became possible to analyze the complex spatial relationships between the various datasets.

As referenced in Chapter 2 a data clearinghouse is housed at Montana State University Library. All project data and reports will be housed at this site which can be found at the following; http://geoinfo.msl.mt.gov/Home/data/yellowstone_river_corridor_resource_clearinghouse.

4.2 Land Use Change

The following chapter summarizes the land use changes and trends identified within the Yellowstone River corridor. A compete discussion of the analyses performed in this investigation is contained in Appendix 1 (Land Use).

4.2.1 Introduction

Land use change was examined for the entire Yellowstone River corridor, from Gardiner at the north entrance to Yellowstone National Park to the Yellowstone River's confluence with the Missouri River in northwest North Dakota.

The land use changes detailed and discussed in this chapter were identified from aerial photographic coverage of the Yellowstone River corridor. The first data point is 1950, the earliest available series of photography for the complete river corridor. With some limitations, other data points from aerial photography include 1976, 2001, and 2011. Because this is an analysis of land use conversion, it relies on the interpretation of aerial photography to determine where human activity has changed the natural condition of the land to some other use, such as housing or irrigated agricultural fields. A four-tiered schema was used to attribute all mapped land use polygons for each year. This allowed the data to be analyzed at a variety of scales (e.g., Tier 1 – agricultural vs. non-agricultural land, or Tier 3 – irrigated vs. non-irrigated agricultural land).

Land use is defined for this study as an activity that is either clearly identifiable from an inspection of the aerial photography or still appears to be in its natural condition. For example, easily identifiable land uses are irrigated agriculture land use with defined fields and irrigation structures; urban land use, where streets, business, industry, houses and other city-based activities have are present; or transportation corridors, such as Interstate or railroad lines. Along the river, land use types include riparian forest (for the Yellowstone the most noticeable forests are the cottonwood galleries in the riparian area) or grassland areas. As, it is not possible to consistently identify whether natural-appearing lands are grazed or not, no effort was made to determine the extent of grazing in the land use mapping datasets.

Land use can also be put into place through location of an activity at a single geographic point, for example the construction of Yellowtail Dam on the Bighorn River. Although the dam only converts the land surface at a single location, its effects influence the river and land cover for long distances, changing the nature of the river channel, altering the hydrological annual cycle downstream from the dam, and affecting the adjacent riparian areas in various ways. Other land uses, like transportation infrastructure, occupy only a small amount of surface area, but can have widespread effects. For example, railroad roadbeds can isolate floodplains at a far greater scale than the mere footprint of the railroad as they run for miles adjacent to the river acting as a dike or levee and preventing normal flood processes. Because it is not the conversion of acreage itself, but the effect on other river processes, this type of land use effect is addressed in the following sections: hydrology, hydraulics, geomorphology, and biology.

The examination of land use change and conversion in this section is focused on two nested areas of the Yellowstone River corridor: (1) within the 100-year inundation area, a GIS-modeled area that approximates the 100-year floodplain; and, (2) within the Total Mapped Area, which encompasses the 100-year inundation area plus 500 meters on either side of the river.

General findings and observed land use trends include the following:

- The Yellowstone Valley, at the beginning of the study period (1950) was overwhelmingly in general agricultural land use (greater than 95 percent in all regions). Irrigated agriculture was largely in place, except for Region D and some scattered reaches in other regions

- Region PC, which includes the entirety of Park County at the upper end of the study area, began to evolve into a socioeconomic base that showed the influence of its place in proximity to Yellowstone National park, its recreational opportunities along the river and in surrounding national forests, and its scenic setting. Agricultural land use dropped by 15 percent overall and irrigated agriculture declined by almost 50 percent. Those land uses were replaced by exurban residential developments along the river and urban expansion near Gardiner and Livingston.

- Region A, begins at the Park County – Sweet Grass County line and ends at the mouth of the Clarks Fork River in Yellowstone County. It exhibits some of the agricultural loss characteristics of

Region PC along the upper third of the region and, in its last two reaches as it nears Laurel, the beginning of the long stretch of the corridor that supported row cropping (like corn, sugar beets, soy beans). Much of the land use in upper Region A remained in ranching, but ownership has consolidated to some degree, with many new owners coming from out of state. At the downstream end of this region most of the land remained in irrigated agriculture, but subdivisions also appeared as exurban development spread where the influence of Billings turned many developments into bedroom communities commuting to jobs in the greater Billings area.

- Region B, from the Clarks Fork River to the Bighorn River, shows sharp contrasts in land use conversion. Between 1950 and 2011, an urban/exurban mix came to dominate the first three reaches of the region nearest to Billings. But beginning with reach B4, there is an abrupt switch to irrigated agriculture, which remains the dominant land use from its established base in 1950. That land use increased slightly to the end of the region by 2011.

- Region C is the largest region both in area (nearly 150,000 acres, Total Mapped Area) and length (148 river miles). The region runs from the mouth of the Bighorn River to the mouth of the Powder River in Prairie County, and it is consistently in agricultural land use from top to bottom. In fact irrigated agriculture is within 250 acres of 42,000 acres at both 1950 and 2011 within the 100-year inundation zone. The only slight departures from this pattern of agricultural land use were at the only communities of size in this region, Forsyth and Miles City.

- Region D begins at the Powder River and runs to the confluence of the Yellowstone and Missouri Rivers in extreme northwest North Dakota. General agriculture and irrigated agriculture are the dominant land uses. Region D is home to two Bureau of Reclamation irrigation districts, at both the upper and lower ends of the region. This region had the greatest amount of agricultural land use change, adding nearly 10,000 acres of irrigated agriculture between 1950 and 2011, of which the major source was previously non-irrigated agricultural land use.

- Irrigated agriculture land use conversion has had the largest effect on the river corridor, converting some 90,526 acres of land within the 100-year inundation zone in 2011 by leveling the land surface and planting monotypic crops on those acres. Its effect is most critical in the mapped Channel Migration Zone (CMZ), where a relatively small percentage of land conversion (with associated bank armor or other structures) can stop the fluvial and floodplain processes that renew both river channel and its associated natural vegetation and fish and animal habitats.

- Large areas of the valley are in land use classified as non-irrigated agriculture. These lands are generally used for grazing, and depending on the intensity of grazing use, retain the remaining areas of natural vegetation and native wildlife habitat. As such they are a valuable resource for maintaining a sustainable river environment sharing socioeconomic use of the valley with native vegetation and wildlife habitat.

- In aggregate, urban and exurban developments are a small contributor to land use conversion along the river as a whole, but have affected localized areas such as the first three reaches and the city of Billings in Region B and nearly half of the reaches in Region PC. In some cases the amount of acreage converted to urban or exurban land use in a single reach far surpasses the extent of agriculture in a comparable reach setting.

- For most of the river, new agricultural conversion has slowed in recent years, except in Region D, where several reaches show a continuing trend towards more agricultural conversion to irrigation. Whether it is trend or established condition, conversion to irrigated agriculture is the dominant land use in a substantial number of reaches. These conversions have often replaced areas of formerly natural riparian land cover.

- A new agricultural trend has appeared and grown since 2001. Before 2001, there was very little use of pivot irrigation in the Yellowstone floodplain or CMZ, as flood irrigation required less dollar investment. Since 2001, though, pivots have made an appearance at several points along the valley. This trend is of interest because the investment required to put pivot equipment in place leads to a greater likelihood that the investment will be protected by armoring the river banks, thus leading to potentially greater effects on channel migration.

4.2.2 Land Use Change Pre-1950

In order to understand the current mix of land uses in the Yellowstone corridor, it is important to review the human occupation of the Yellowstone prior to the 1950 start of the study.

Along the Yellowstone River in Montana, human inhabitants prior to the settlement of Euro-American pioneers were hunters and gatherers and had little to no long term effect on the river valley.

Except for occasional transit across the area by early explorers like Lewis and Clark or intermittent use by fur trappers in the first half of the 19th century, the Yellowstone River area first began experiencing Euro-American influence on a regular basis in the 1860s, but their use of the area was still transitory. Both the Bozeman Trail and the Bridger Trail traversed some of the upper Yellowstone corridor, bringing supplies from the Midwest to the gold fields, and the first cattle herds were driven north from Texas to as far north as the Big Dry area north of Miles City. It was not until after the Sioux War from 1876 to 1877 that meaningful Euro-American settlement occurred in the Yellowstone corridor. The completion of construction of the Northern Pacific railroad from Minneapolis—St. Paul through Montana to the Pacific Northwest in 1883 began the era of expansive settlement, although some settlement began occurring with the short-lived steamboat era immediately prior to the coming of the railroad. The railroad, along with federal homestead laws, required wood for fuel and encouraged support facilities and promoted farming and ranching along the length of valley through the last two decades of the 19th century. Still, populations were small. In 1880 the U.S. Census “counted only 588 people living in the vast area between present-day Livingston and Miles City. Far fewer residents lived in the rangeland east of Miles City” (Van West 1995).

By 1885, a group of businessmen from Miles City had begun constructing a diversion dam upstream of Miles City on the Tongue River, and some limited irrigated agriculture began along the south side of the Yellowstone River (Montana State Engineers Office 1948). A private irrigation company also constructed a ditch in 1892 to irrigate the area west of Billings (Montana Extension Service 1932). After 1900 the pace picked up as the newly formed Bureau of Reclamation initiated two substantial irrigation projects downstream of Billings and near the mouth of the river in extreme eastern Montana and northeast North Dakota (Dick 1993, 1996). Population growth quickened as well. Billings grew from a population of 836 in 1890 to 3,221 in 1900.

Between government sponsored irrigation projects and private efforts, and notwithstanding the economic depression in the 1930s and World War II in the 1940s, by 1950 (the point when this study begins), the agricultural development of the Yellowstone Valley was largely in place. Only in the farthest downstream Region D near the Missouri River confluence was there significant growth in irrigated agricultural land use following 1950.

The railroad portion of the transportation network was also in place long before 1950. The early development of the Northern Pacific railroad through the Yellowstone corridor was only the first of several rail systems to add their footprint to segments of the corridor. The Northern Pacific extended a branch from Livingston on the main line to Gardiner as an entry to Yellowstone National Park in 1902. Two other national rail lines had connected to Billings between 1894 and 1906. The Chicago, Burlington, and Quincy Railroad built into the Yellowstone corridor at Billings, providing a connection to Omaha, Nebraska to the east and Denver, Colorado, to the south. The Great Northern Railroad along the northern tier of Montana extended its lines to Great Falls and then Billings to access the Yellowstone River area. Also early in the twentieth century the Milwaukee Railroad, another transcontinental line, built into Montana entering the Yellowstone corridor at Fallon and traversing the valley until taking a northwest route at Forsyth (Van West 1995).

U.S. and state highways gradually connected Yellowstone corridor communities. For much of the early twentieth century the roads were relatively primitive, but the Yellowstone corridor was completely tied together by paved highways before 1950.

By 1950, many individual farmsteads existed throughout the Yellowstone Valley, but most communities were small, and urban-type settlement was restricted within the bounds of those towns and small cities. Even Billings' footprint only marginally affected the river corridor. Exurban growth had not begun in this area, so the rural residential pattern that existed at this time was closely associated with town and city boundaries and very limited.

4.2.3 Land Use at 1950

1950 marks the earliest complete historic imagery data set for the Yellowstone corridor. As such, it marks the earliest full understanding of human use of the corridor subsequent to human occupation.

4.2.3.1 Irrigated Agricultural Land Use at 1950

By 1950, most irrigated agricultural land use throughout the Yellowstone corridor was already in place. For the Total Mapped Area, 94 percent of the area was in general agricultural land use. Moving closer to the river that same percentage applies with about 95 percent of both the Inundated Area and the Channel Migration Zone (CMZ) were also in general agricultural land use (Figure 4-1).

Focusing on the areas in closer proximity to the river to evaluate irrigation, by 1950, 40 percent of the 100-year inundation area had been converted to irrigated agriculture in the entire river corridor, but there was variation among the five regions. On the low side, 28 percent of the inundation area in Region B had been converted to irrigated agriculture and Region PC was also just under 30 percent. At the other end of the scale, Region C had seen approximately 50 percent of its inundation area converted to irrigation (Figure 4-2).

Considerable agricultural land classified as non-irrigated agricultural land use remained in 1950 in all regions along the river in the Total Mapped Area. For the corridor as a whole, that amount is 67 percent of the total non-irrigated corridor acreage of 233,224, but the single figure masks a 16 percent swing among regions. The lowest amount was 59 percent of total acreage in Region C, with the highest amount about 75 percent in Regions PC and B (Figure 4-3).

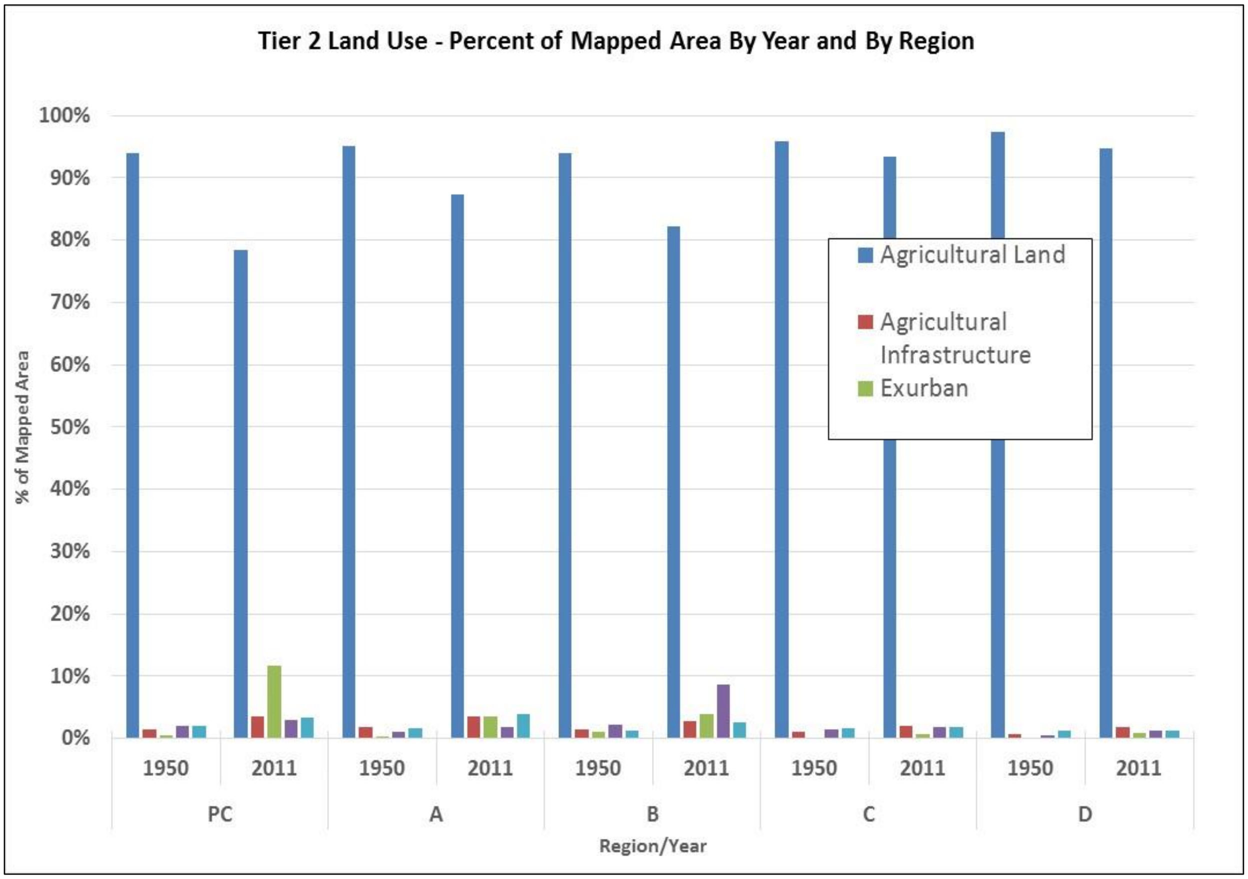


Figure 4-1 Major land use categorization in the total mapped area of the Yellowstone River corridor

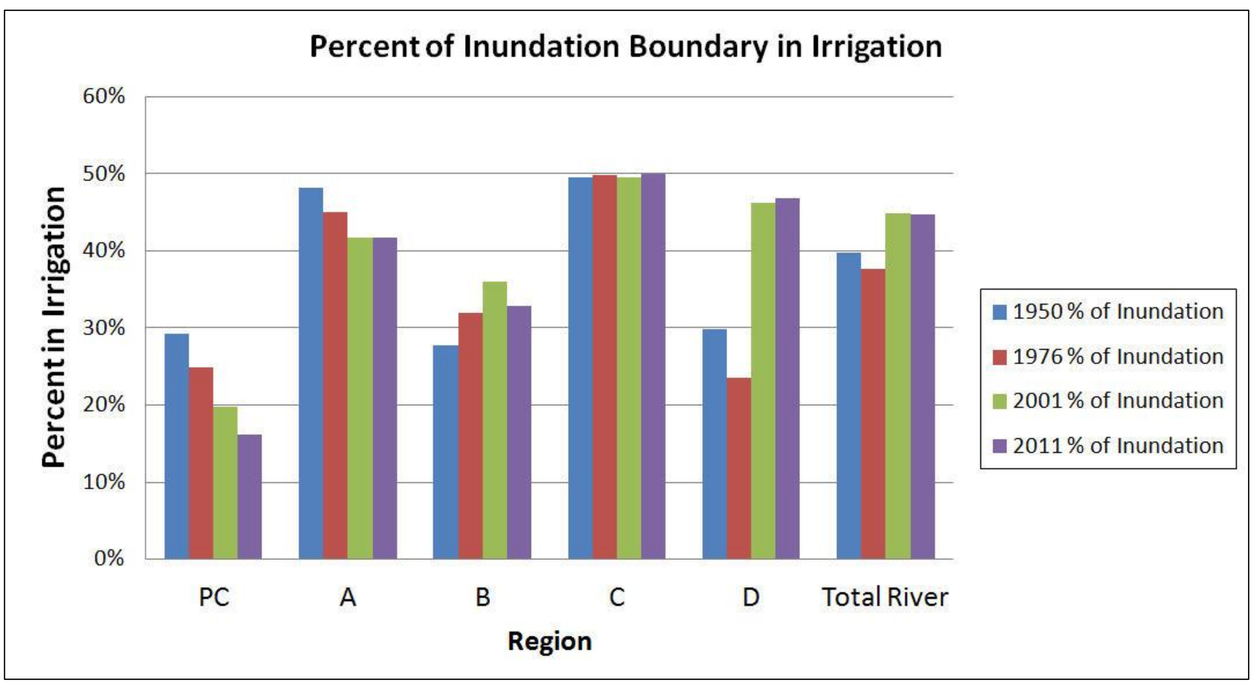


Figure 4-2 Irrigation in the 100-year inundation area, by region

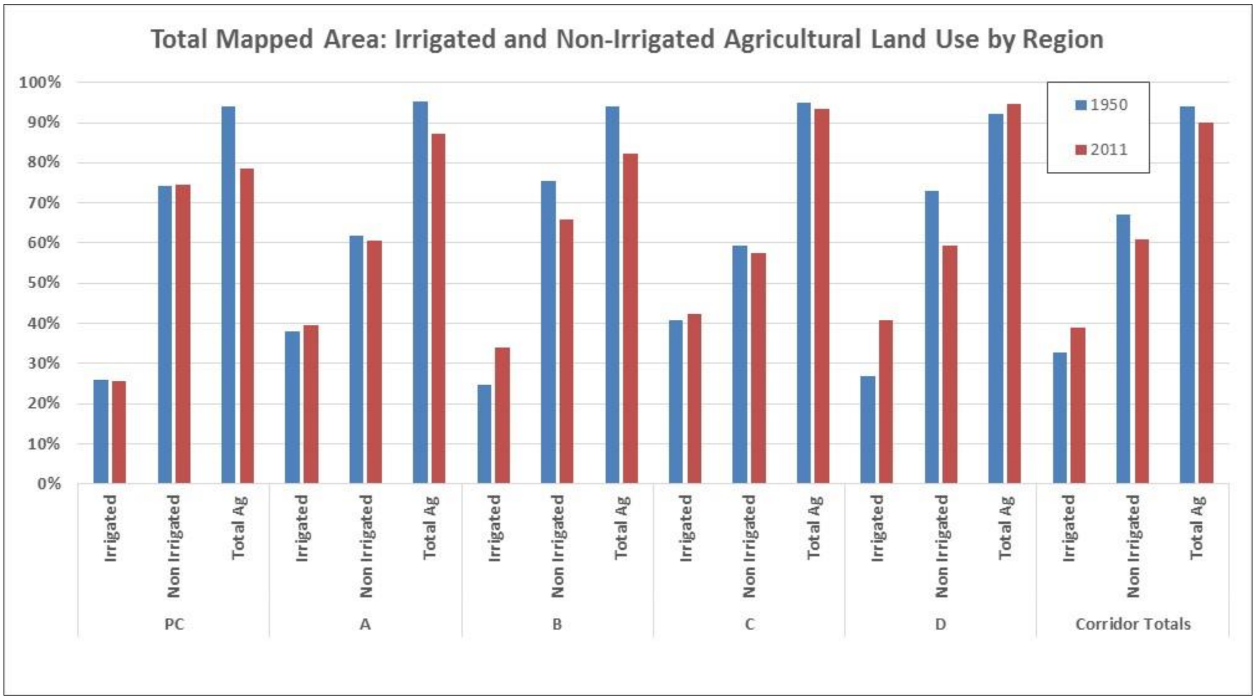


Figure 4-3 Comparison of Agricultural Land Uses: Irrigated to Non-Irrigated

4.2.3.2 Other Land Uses at 1950

In 1950, conversions of land to the other principal land uses had a small footprint. Urban and exurban development converted the greatest amount of acreage after agriculture. They are grouped together for the 1950 discussion because the amount of urban plus exurban development only amounts to 5,942 acres, or about 1.6 percent of the 369,720 acres in the Total Mapped Area.

The Billings region represents the most acreage in urban and exurban land use in 1950, which is 3.3 percent of Region B's land acreage of 52,762, keeping in mind that the study area does not cover entire municipal limits. The other area worth noting for urban/exurban development is Park County. In 1950, Livingston's footprint in the study area was fairly substantial at 730 acres, but only 158 acres had been converted to exurban development in the entire county. Looking at areas closer to the river, the entire Yellowstone River 100-year inundation area had only 1.4 percent of the land surface devoted to urban and exurban land uses in 1950 (2,797 acres).

Transportation also was well in place by 1950. As a land use, transportation is only a distant third place to irrigated agriculture. In 1950, every region was completely crossed by a network of auto roads and railroads. Yet its acreage footprint in the 100-year inundation area, where it is of most concern, was not more than 1.1 percent in any region (ranging from 0.4 percent in Region D (410 acres) to 1.1 percent in both Region PC and Region A, at 153 and 358 acres, respectively).[1]

The small amount of land use conversion belies the overall effect of the transportation system on the valley however. Refer to later sections in Chapter 4 that detail how transportation affects aspects of hydrology, geomorphology, and the riparian vegetation systems and their relationships to transportation

[1] The apparent discrepancy in amount of acreage compared to percentage is explained because the Regions vary significantly in river and valley miles; thus, the acreage in Region PC represents a larger part of a small area than does the acreage in Region D. Regions were selected for other factors than distance, including biological makeup and intersection with major tributary drainages.

features. The direct impact of building roads and railroads is the conversion of a narrow but continuous strip of land use for the prism that makes up the roadbed for any transportation component—railroads, public highways, and the federal interstate highway system. These road prisms have secondary impacts to their surroundings, by forming dikes that prevent floodwaters from accessing floodplains, through the accidental protection provided to other land use activities, and by encouraging greater development of irrigated agriculture fields, housing, and industrial development close to the river banks. Another secondary effect includes eliminating the river processes that renew riparian systems along the river by not allowing flooding and seed spread from the river to the floodplain and preventing new soils from forming from flood events, again by isolating the floodplain.

The railroad is demonstrably the largest contributor to these effects. With the rigidity of its tracks and the number of heavily loaded cars moved by engine power, the railroad has sought the least gradient that it can feasibly use for construction. This has led to long mileage of tracks as near the river as can be made feasible, and thus the dikes formed by the raised roadbed affect large acreages of floodplain. Extensive modification of river channels is also created to protect the bankside railroad tracks.

Highway systems are much more flexible in design and have not followed the river to nearly the same extent. In most cases, the greatest impact occurs at bridges where the road crosses the Yellowstone River. See Appendix 1 (Land Use) for an example analysis of the difference in river proximity for railroads versus roads.

4.2.4 Post-1950 Land Use Trends

Agriculture, considered over the total mapped area of the Yellowstone River corridor, has been the major economic driver of life along the river. As the valley moved on from 1950 it began to diversify in some areas, principally in the upper three regions of the river. While 94 percent of the land (347,445 acres) along the entire valley was in some form of agriculture in 1950, with only small regional differences, by 2011 only Regions C and D maintained such a high degree of agricultural land use. The changes show that Region PC and Region B are becoming more diverse. As Region PC became an economy more oriented to amenity values such as recreation and tourism, agricultural land use dropped over 15 percentage points relative to its 1950 status. While Region PC is the smallest in total acreage within the river corridor, meaning that the actual acreage in agricultural use dropped only about 5,700 acres, nearly all of that acreage, or 4,200 acres, was converted to urban and exurban land use, changing the character of the valley from its agricultural roots. Region B containing Billings, the largest urban concentration in Montana, moved a different direction, becoming more urban. It saw 12 percent or 5,899 acres converted from agricultural to urban, exurban, and transportation uses. Region A stayed more rural than the Region PC, with over 87 percent of its land surface remaining in agricultural use.

4.2.4.1 Agricultural Land Use Change in the 100-year Inundation Area

The Inundation area was developed using a GIS-based model that approximates the 100-year floodplain. It is assumes that all dikes and levees are permeable, and thus contains areas of historic floodplain that would not be in a traditional hydraulic floodplain model. The Inundation area should not be confused with the 100-year floodplain hydraulic model developed for this study. Additionally, the Inundation area has no regulatory application.

For the uppermost two regions, PC and A, there was a substantial loss of irrigated agricultural land within the Inundation area. Starting from an already small total of 2,537 acres of irrigation within the inundation area, the Region PC acreage in irrigation dropped by nearly half to 1,406 acres by 2011. In the larger Region A, the percentage change was less dramatic, but it involved about the same number of acres of change. In 1950, irrigated acreage in Region A was 10,085 acres, but dropped to 8,733 acres by 2011. Figure 4-2 shows a clear trend of declining irrigation in both regions.

Within the 100-year inundation area, it is interesting to note that the change trends are concentrated in individual reaches of the river. In Region PC the large acreage losses were concentrated in 5 of the 21 reaches, and accounted for 1,069 of the 1,131 net acres lost in that region. Those included reach PC7 (near the small communities of Emigrant and Chico Hot Springs Resort) and PC10 (near Pine Creek in the Paradise Valley portion of the region), an area highly regarded for amenities like Chico Hot Springs, spring creek fisheries near Pine Creek, and the general beauty and striking scenery of the surroundings. Other large acreage losses occurred in three reaches just downstream from the city of Livingston and are noted for subdivision development.

The declines in agriculture were not limited to irrigated agriculture. The non-irrigated agricultural land also declined, and more consistently than the irrigated land. In contrast to the 5 reaches experiencing irrigated agricultural losses, 12 reaches had declines in non-irrigated lands. Declines in both irrigated and non-irrigated agricultural land use between 25 and 35 percent can be seen in several reaches of Region PC in Figure 4-4.

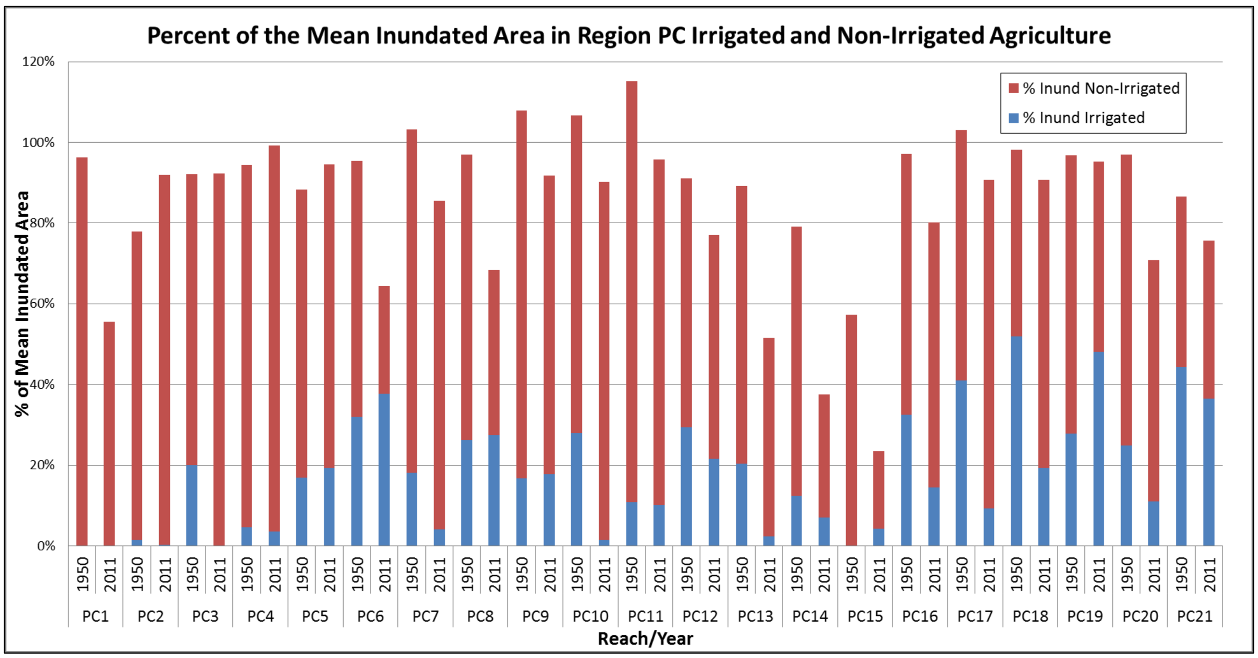


Figure 4-4 Changes in Agricultural Land Use in Region PC, 1950 – 2011

These declines in irrigated agricultural land use are largely replaced by gains over the 60-year study period in urban and exurban development. While there is a clear and steady trend of declining irrigation land use, it is replaced by an opposite trend of population growth and urban/exurban expansion in the same reaches. See the urban/exurban section for further detail of these trends.

Region A, which also lost irrigated agricultural lands (down 1,352 acres), shows no clear cause. Nearly all of the 18 reaches lost irrigated acreage (ranging from 24 to 279 acres), with only 3 reaches gaining a total of 110 acres. Reach A6, which lost 279 acres of irrigated land, gained 105 acres of exurban development and 105 acres of non-irrigated land. There also was no clear trend of when the change in relative acreages occurred. In some cases, it happened by 1976, but in others it only happened by the 2000s. One possible explanation is a change in ownership from primarily family ranches depending on hay for livestock feed to many less than full-time resident ownerships from out-of-state, which has lessened the dependence on irrigated hay. These property purchases have occurred only as properties have become available for sale, and this may explain the lack of a uniform trend. For the most part the ownership change has not been accompanied by exurban development. Only three reaches, A6 (three reaches down river from Big Timber), A13 (which includes the town of Columbus), and A18 experienced significant acreage gains in urban/exurban area.

The A18 exurban development occurred in the last reach of the region, which is within 12 miles of Billings in Region B. The lower part of Region A has been part of the urbanization process occurring in and around Billings, and serves as bedroom communities for commuters to the Billings job market.

Further down river there has been little conversion of agricultural lands to other uses within the Inundation area. In Regions B and C, slight increases in irrigated agriculture occurred in the 100-year inundation area but only as small percentages. These changes can be seen in Figure 4-5 and Figure 4-6.

Region B follows the general trend seen in the lower Yellowstone corridor, where agriculture is the major land use. Region B has only two reaches where irrigated agricultural lands have lost acreage: B2 and B7. B2 is associated with the main part of the city of Billings and lost 259 acres of irrigated land, which was 98.2 percent of the irrigated land in the reach. That shift occurred by 1976, after which there has been essentially no change in this land use category. In most reaches in this region of the Yellowstone, gains in irrigated acreage are relatively small and may represent small changes in agricultural emphasis over the years. Irrigated agriculture reached its greatest extent by 2001 but had lost acreage by 2011.

Region C saw a slight increase in irrigated agricultural acreage within the Inundation area over the 60 years of the study. Reaches or clusters of reaches that gained irrigated agricultural acres alternated with other reaches that showed a loss in irrigated acreage. In most cases, these gains and losses alternated with non-irrigated agricultural lands, which often gained when the irrigated lands had losses and lost when the irrigated lands had gains. An independent variable was the amount of acreage eroded by river channel migration, which often balanced the loss/gain imbalances in agricultural lands. In fact, over the 21 reaches of Region C, the net acreage gained by irrigated land in the Inundation area was 358 acres, while the same 21 reaches saw a net gain of 1,175 acres of non-irrigated agricultural land. At the same time there was a loss of 1,351 acres of channel. The total change, therefore, interplay among channel, non-irrigated agricultural lands, and irrigated lands, was 2 acres. Thus not much change occurred in the relationship between agriculture and the river over this region. The two obvious declining reaches for agricultural lands are C10 and C17 and are explained by increases in urban and exurban land use associated with the towns of Forsyth and Miles City.

While there is stability in this region, Figure 4-6 graphically shows one area where several reaches exhibited a high level of irrigation land use. Of the 21 reaches in the region, eight have converted over 50 percent of the inundation area to irrigated agriculture, and six are over 60 percent converted to irrigation.

There are several reaches in this region that have a greater range of channel complexity, islands, and riparian forest. These reaches could be beneficial in sustaining native vegetation and natural habitat with attention to side channel preservation and minimization of encroachment. Reach C7 contains one of these areas, pictured in Figure 4-7. The figure indicates the wide meandering channel in the non-colored area, while the yellow depicts non-irrigated agricultural land, showing that much of the area is not irrigated (irrigation is shown in green).

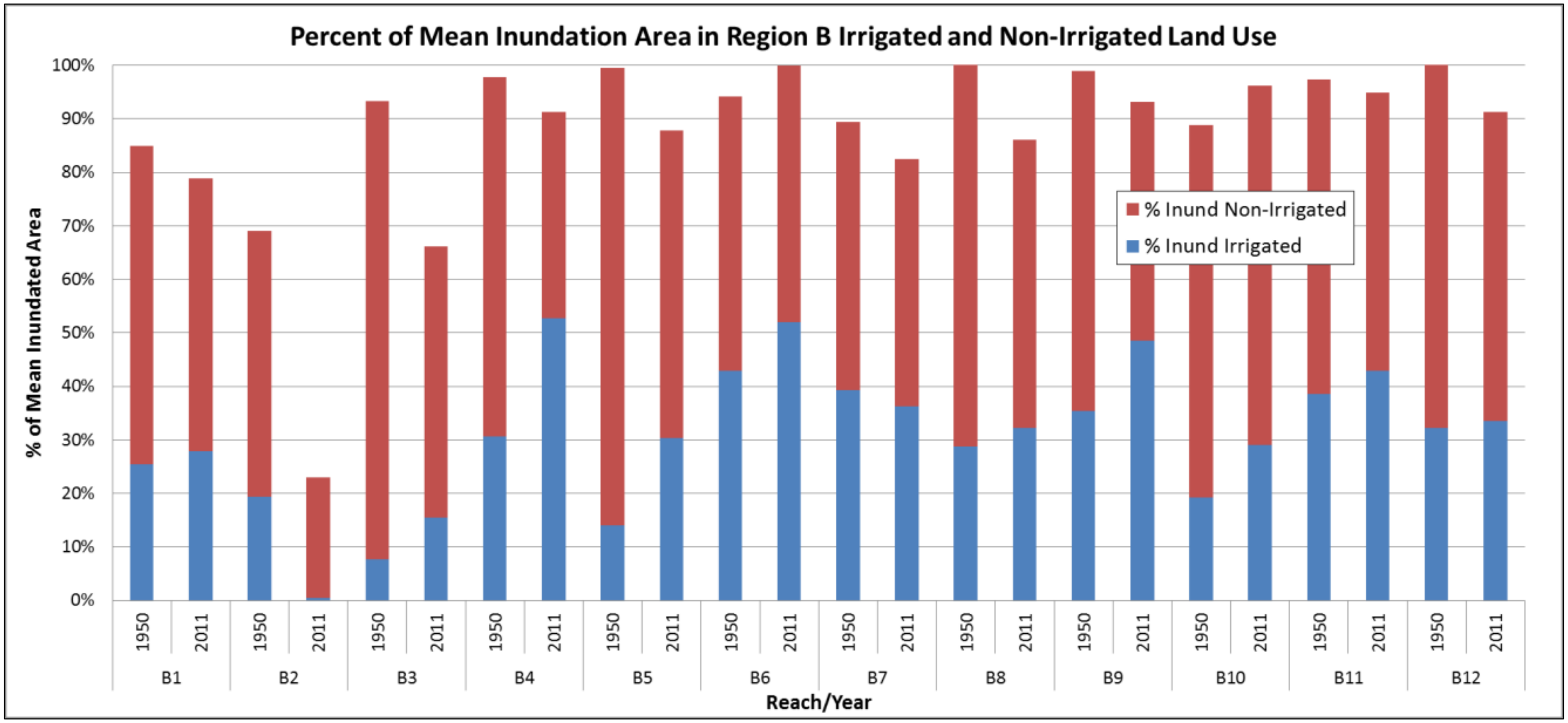


Figure 4-5 Changes in Agricultural Land Use in Region B, 1950 – 2011
Note: *Reach B2 where all irrigated land use had been eliminated by 1976 within the Inundation area. Also note that in Lower Region B there is some growth in irrigated agriculture, but displaying the non-irrigated changes mask that trend.*

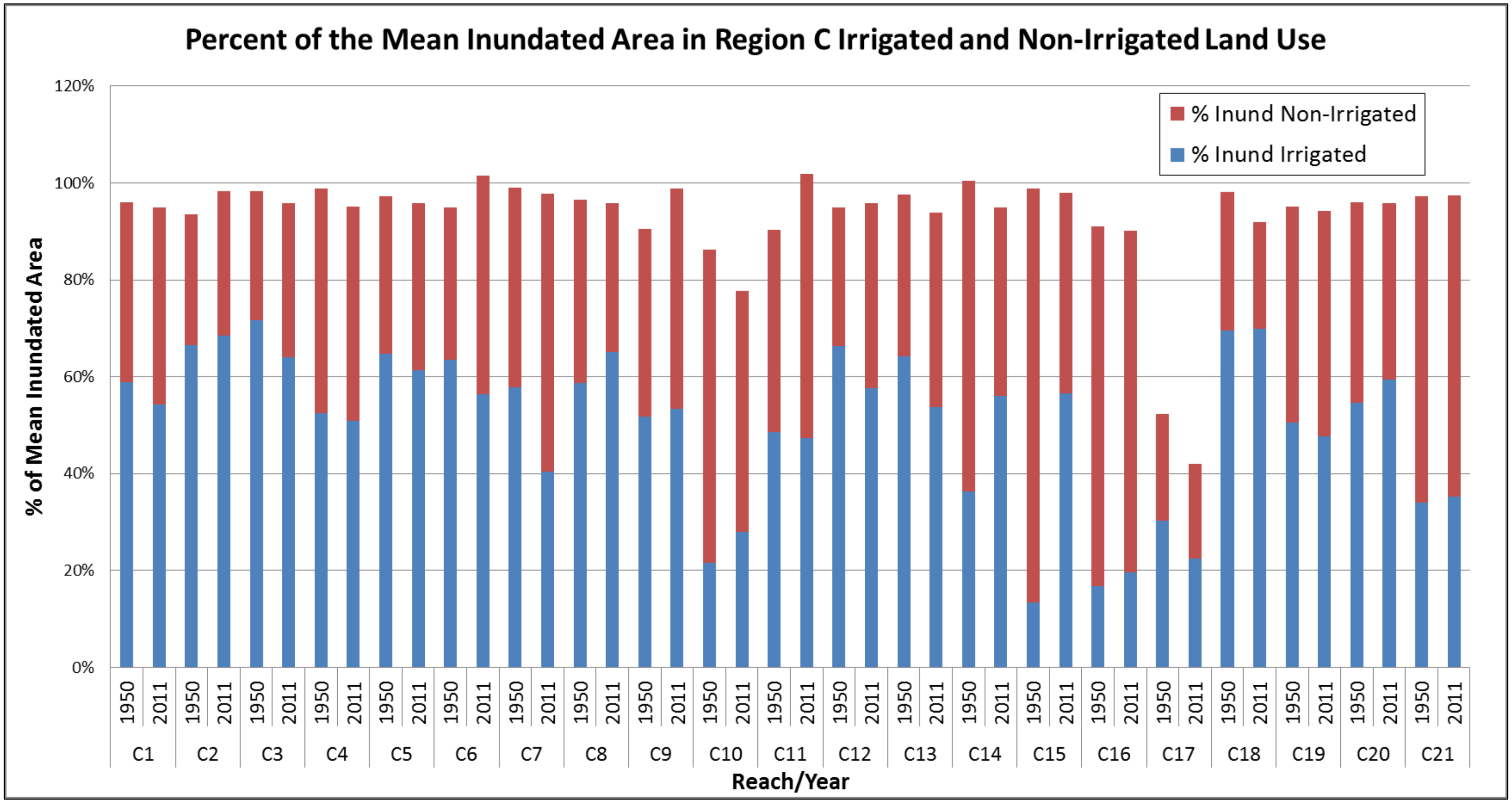


Figure 4-6 Changes in Agricultural Land Use in Region C, 1950 – 2011

Figure 4-7 Reach C7 Also known as Mission Valley; a particularly complex reach with preserved riparian forests and channel movement potential

Region D experienced a substantial increase in irrigated agricultural land within the Inundation area, increasing 10,743 acres over the 60-year study period; roughly a gain of one-third in irrigated land area. As noted earlier in the land use section, agricultural land has been the dominant land use at over 95 percent since 1950, so the gains in irrigation came from conversion of non-irrigated agricultural lands, often through riparian clearing.

The counterpart to the agricultural expansion is loss of native vegetation and habitat. Region D has some of the most complex reaches of the river, with formerly wide expanses of complex riparian forest that experienced a trend of continued loss of riparian forest to agriculture land use from 1950 through 2011. As Figure 4-8 shows, irrigated agriculture land use increased to 60 percent of inundation area in 2011 for the final five reaches of the Yellowstone, with Reach D at 80 percent.

As opposed to the floodplain in Region C, where losses and gains in agricultural acreage within the Inundation area almost cancel out, Region D has only one reach that lost irrigated acres in the last 60 years and two other reaches that had gains of nearly 300 acres of irrigated agricultural land. The remaining 13 reaches had gains greater than 300 acres (some significantly higher). The first three reaches of Region D are within the Buffalo Rapids Irrigation District, a Bureau of Reclamation project, and averaged a gain in acreage of nearly 530 acres each. This district also saw considerable additional improvement in pumping capacity and field delivery capacity due to investment by the USBOR and NRCS in the years around 2000.

At the lower end of Region D, the final five reaches, D12 through D16, experienced significant growth of irrigated acreage in the Inundation area totaling 5,403 acres or almost half of the total gains in the region. The final three reaches averaged a gain of 1,800 acres each. Again, these reaches are part of a Bureau of Reclamation project, the Lower Yellowstone Irrigation Districts.

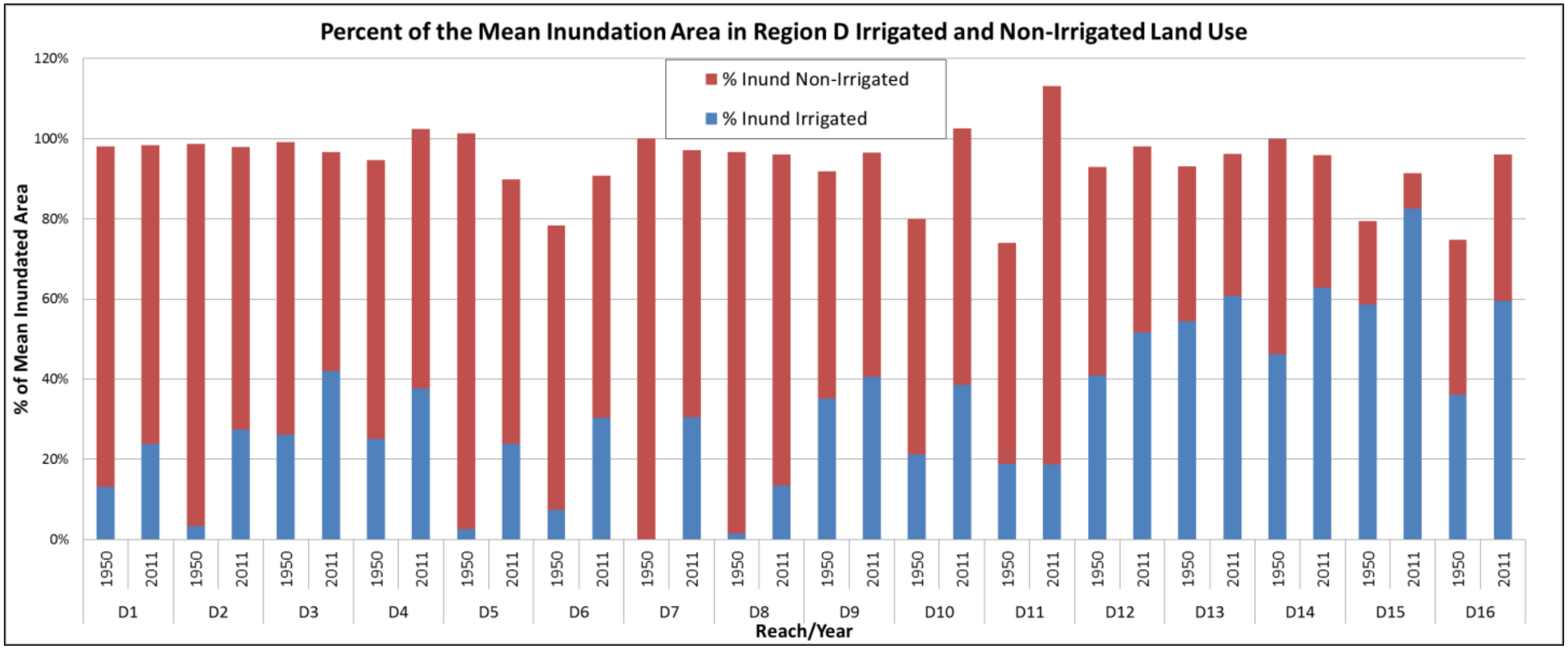


Figure 4-8 Changes in Agricultural Land Use in Region D, 1950 – 2011

The remaining growth in irrigation use fell in between these two extremes. Seven of the remaining ten reaches saw significant irrigation acreage growth, between 359 and 688 acres in each reach. Two of the other three experienced growth as well (albeit small numbers): 111 acres in Reach D9, the location of Intake Diversion serving the Lower Yellowstone Districts, and D13, in which the town of Sidney is located just out of the river corridor but has significant industrial facilities (a coal-fired electrical generating plant, and a sugar beet factory located near the river occupying over 120 acres). The remaining reach, D11, saw a drop of 8 acres of irrigated agricultural use in the 60-year study period. That reach, along with D12, is home to two significant wildlife management areas on the lower Yellowstone, Elk Island, and Seven Sisters, which have maintained the majority of the immediate floodplain in natural riparian vegetation.

The federal Bureau of Reclamation irrigation projects in Region D are associated with most of the gains in irrigated land the north and west bank on through Reach D6 into the Glendive area. The pumping plants for this last major project to be developed by the Bureau were not completed until 1950 and build out of the principal canals occurred in the first few years of the 1950s.

The largest irrigation project on the Yellowstone River is the Lower Yellowstone Irrigation Project, one of the Bureau's first five projects in the U.S. The project area begins with Intake Diversion Dam in Reach D9 and delivers water to about 55,000 acres on the west side of the Yellowstone, ending at the confluence with the Missouri River in North Dakota. In these lower reaches of the Yellowstone, besides the federal investment in irrigation, the sugar beet factory at Sidney has provided a significant incentive to invest in irrigated agriculture since its construction in the 1920s. This combination of factors created the longest stretch of agricultural investment on the Yellowstone in the latter half of the twentieth century. With the major increase in acreage following 1950, Region D has reached approximately the same amount of agricultural development in the inundation area in terms of percentage as the rest of the regions had achieved prior to 1950.

4.2.4.2 Agricultural Land Use Change in the Channel Migration Zone (CMZ)

The Channel Migration Zone (CMZ) defines an area of likely river occupation over the next 100 years due to either channel migration or avulsion processes. While the Inundation area represents areas likely to get wet at a 100-year flood, the CMZ represents the hazard of losing land due to river movement.

In all five regions irrigated agriculture land use in the CMZ follows the same pattern as in the inundated area. In the reaches where irrigated agricultural use was heaviest in the inundated zone, irrigation also encroaches into the CMZ in the same reaches, although the degree to which it encroaches is not always to the same intensity. More detailed discussion of the land use within the CMZ can be found in Appendices 1 and 4 (Land Use and Geomorphology).

Region D is an example of a new trend appearing in irrigation along the Yellowstone, mainly since 2001, at least in areas close to the channel. Prior to 2001, there was very little pivot irrigation in the CMZ. However since that time it has begun to appear. Pivot irrigation requires considerable investment in mechanical apparatus, and when placed in the CMZ it faces threat of being affected by the migrating channel. In many reaches of the river, high investment costs encourage bank armoring, thus interrupting the fluvial and riparian processes that maintain the sustainability of the river. Figure 4-9 shows the recent appearance of pivot irrigation in the CMZ. Figure 4-10 and Figure 4-11 show examples from reach D10 where irrigation has encroached on the river within the CMZ, and has been converted to pivot on the edge of the channel. Some erosion into this pivot irrigated field has already occurred. The source of Figure 4-10 is the 1950 aerial photography, while Figure 4-11 is from 2011. The dashed red line on the left (west) side of the photo can be used to orient the reader to the conversion of the riparian vegetation to agricultural land use. Note that these figures also show extensive riparian clearing, as well as a blocked side channel to the left of the river mile 58 marker.

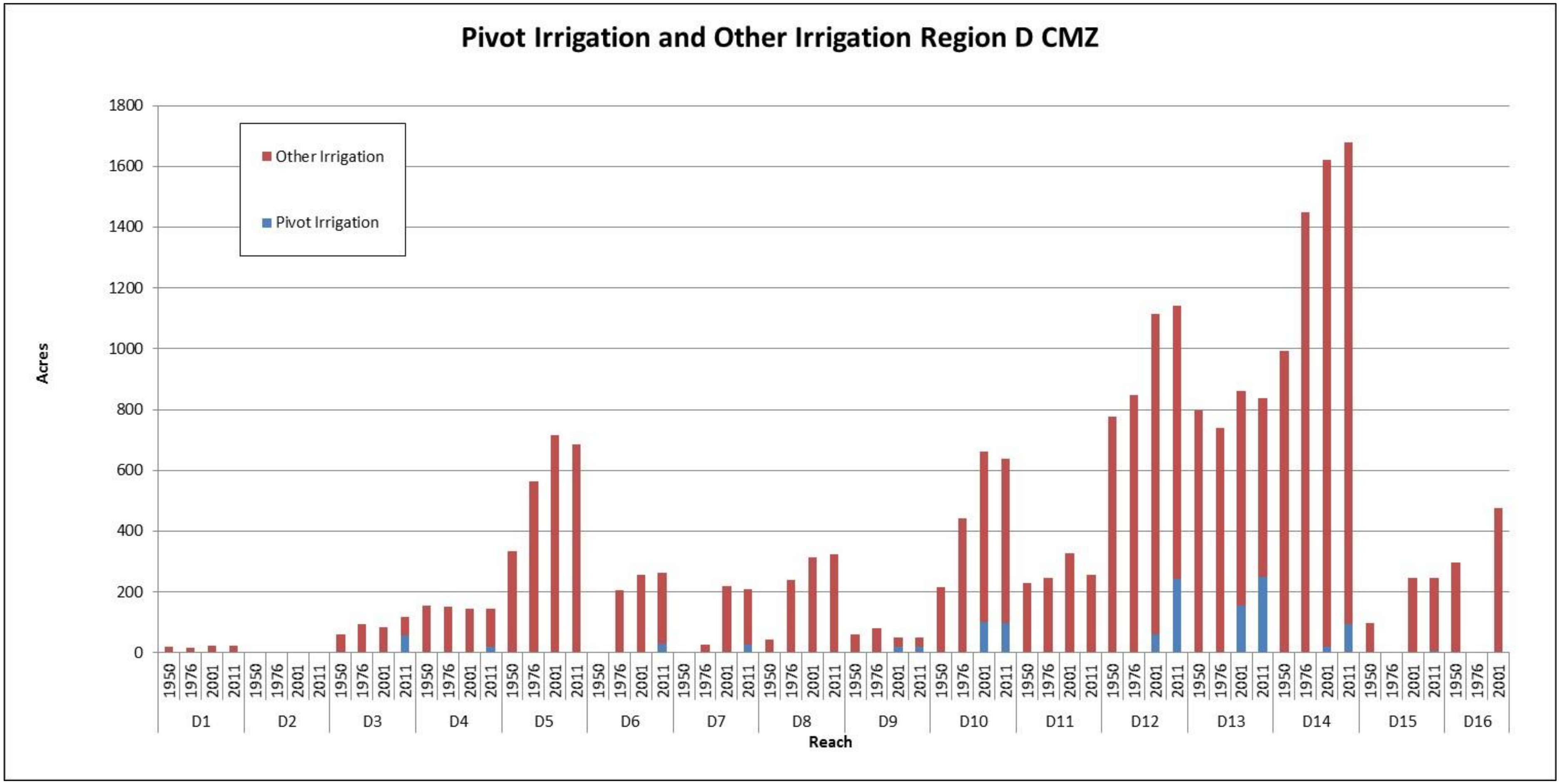


Figure 4-9 **Appearance of Pivot Irrigation in Region D CMZ**

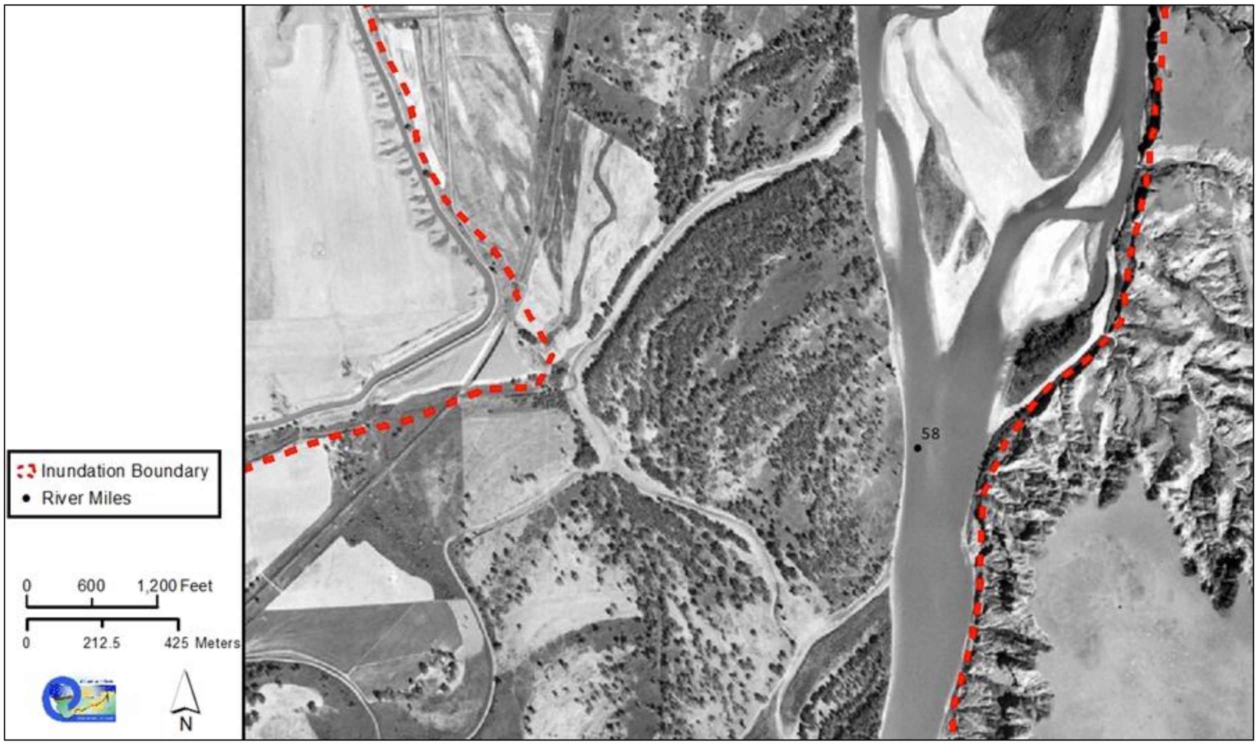


Figure 4-10 **1950 View of a Portion of Reach D10 Showing predominant Riparian Forest Land Cover Immediately Left of the River Mile 58 Mark**

Figure 4-11 **2011 View of Reach D10 CMZ Location Shown in Figure 4-10**

Note: *River Mile Mark 58 and the land use adjacent to it, with pivot irrigation next to the river bank*

4.2.4.3 Land Use Change Related to Transportation

Within the 100-year inundation area, transportation land use was below 1 percent in 1950, occupying 2,538 acres. Even the addition of the interstate highway system which runs through the valley for hundreds of miles (except for the topmost reaches of the river from Yellowstone Park to Livingston and bottommost reaches from Glendive to the confluence with the Missouri River), only brings up the land occupied by transportation systems to 1.1 percent or 3,126 acres.

However, the small amount of area covered by transportation facilities and roadbed does not reflect the real impact of transportation and particularly railroad roadbed. The railroads were built as close as possible to the river because that kept the gradient at the minimum possible, an advantage to long heavily-loaded trains, saving on fuel and keeping locomotive power to a minimum.

The roadbed near the river often acts as a dike or levee, in effect preventing the river from flooding beyond the railroad line. It also has the effect of isolating the floodplain and preventing the river's access to the lands it needs to replenish riparian vegetation, dissipate floodwaters, and deposit new soils to the riparian area. The effects of floodplain isolation are covered in more detail in Sections 4.5 and 4.7.

Between 1950 and 2011, there were only two substantial changes to the transportation infrastructure. First, in the 1960s and early 1970s the interstate highway system was constructed through Montana. Although it features continuous, parallel, roadbeds accommodating four lanes of traffic with minimized grade differences, i.e., major amounts of cut and fill to minimize grade changes, it was built outside of the influence of the Yellowstone River for the most part. There are only localized instances where there are specific effects on the river, such as highway bridges over the Yellowstone. Two of these bridge complexes do create problems with the river, at Livingston where the grade to the bridges has left only a narrow gap for the river to pass and for access roads to the inhabited Ninth Street Island and at Glendive, where the bridge grade has blocked a formerly active side channel. For most of the interstate routes along the Yellowstone, the twin grades are at considerable distance from the Yellowstone floodplain. Where they are closer to the river, in all instances except for bridges, the interstate highway right-of-way is on the valley edge side of the railroad right-of-way and does not directly influence the river's flow.

Second, the abandoned Milwaukee Railroad follows the Yellowstone River from Fallon to west of Forsyth, a distance of 114 river miles (River Mile 131 to River Mile 245) and affects parts of reaches in Regions C and D (C9 through C21 and D1 through D2). Soon after it enters the river corridor in reach D2, it crosses the major railroad in the river corridor (the Burlington Northern Santa Fe) and thereafter is nearer the river whenever it runs on the south side of the Yellowstone River, which it does for 12 miles near Terry and again for 17 miles near Miles City. Even though the Milwaukee Railroad went bankrupt in the late 1970s and was abandoned in the 1980s, it still acts as a dike for many miles of its former rail bed. The portion of the valley east of Forsyth is particularly problematic where the former railroad is located close to the river from Forsyth downstream for about 40 miles on the north side of the river. In the land use mapping done for the river, the abandoned rail line is not classified as a transportation feature due to its abandoned status, but its floodplain isolation effect remains.

4.2.4.4 Land Use Change Related to Urban and Exurban Development

There is little effect of urban and exurban land use conversion when considered in the context of the entire river corridor and the Total Mapped Area. As described earlier in Section 4.2, in 1950 nearly the entire corridor was rural, with the only community showing much expansion beyond mapped city limits being Billings in Region B. The combination of urban and exurban land use conversion only occupied 1.6 percent of the Total Mapped Area for this study. By 2011, the lower regions of the river had not changed much, having converted only 2.4 percent (5464 acres) of the Total Mapped area in Regions C and D together to urban and exurban land use. However, along the upper Yellowstone River, particularly in Regions PC and B, increased markedly (and because much urban/exurban growth has occurred outside the Total Mapped Area of land use, the total change in land use attributable to urbanization is probably understated). Even limiting analysis to the study area, land use conversion to urban and exurban use in these two regions jumped from about 3 percent of the regions study area (2600 acres) to 15 percent in Region PC (5085 acres) and 13 percent in Region B (6689 acres). As with other land uses, by 2011 Region A had only experienced moderate growth in urban/exurban land use conversion, from 1 percent of the Total Mapped Area to 5 percent.

The 100-year inundation area highlights the change between 1950 and 2011. In 1950, the timeline for the beginning of this study, there were essentially no large subdivisions along the river between the major communities. In the 100-year inundation area, the largest concentration of urban/exurban development was found in Regions B and C, comprising 2,326 of the total 2,797 acres of either urban or exurban development along the entire river, with the 2,797 acres representing about 2 percent of the inundation area in 1950. The entire corridor was distinctly rural with only 420 acres of exurban development and all of that on the outskirts of the major towns of Livingston, Laurel, Billings, Forsyth, and Miles City. Even in 1950, Billings dominated its part of the corridor with 210 acres of inundation area converted to exurban development.

Upper River

The Upper Yellowstone River regions PC and A differ distinctly from the remainder of the river after 1950. These regions experienced a substantial loss in irrigated agriculture acres. In Region PC, those agricultural land use acres were replaced in large part by urban and extensive exurban development. The exurban development is not dense relative to that experienced in many parts of the United States. But it is extensive in that the developments are large acreage lots and extends intermittently from Gardiner at the top of the region to below Livingston, a distance of 74 river miles.

The most extensive exurban developments have occurred in Park County (Region PC). Overwhelmingly that change in land use has occurred since the beginning date of the study of 1950. In 1950, there were only 39 acres of inundation area exurban development in the entire PC region, and that acreage barely registers as a fraction of the total PC Region inundation area (e.g., 0.3 percent). By 1976, the trend of change in land use was well underway, having grown by a factor of 10, with 379 acres of exurban land use conversion. That acreage had almost doubled again by 2001 at 652 acres and in the 10 years to 2011 grew another 18 percent to 768 acres. Those acreages represented a range of 0.7 percent of Reach PC4 to 39.3 percent of PC13 (100-year inundation area). See Figure 4-12 to view the percentage growth in the inundation area.

The 1,038 acres of urban/exurban development in Region PC replaced most of the loss of 1,406 acres of irrigated agriculture in the inundation area, both having occurred over the 60-year study period. The relative percentage of total urban versus exurban acres illustrates the change in land use conversion and nature of land use in Region PC. In 1950 urban acres dominated the category, i.e., 83% of all urban and exurban lands were urban in nature; by 2011 the situation had almost reversed and exurban land use acres dominated, at 80% of the category.

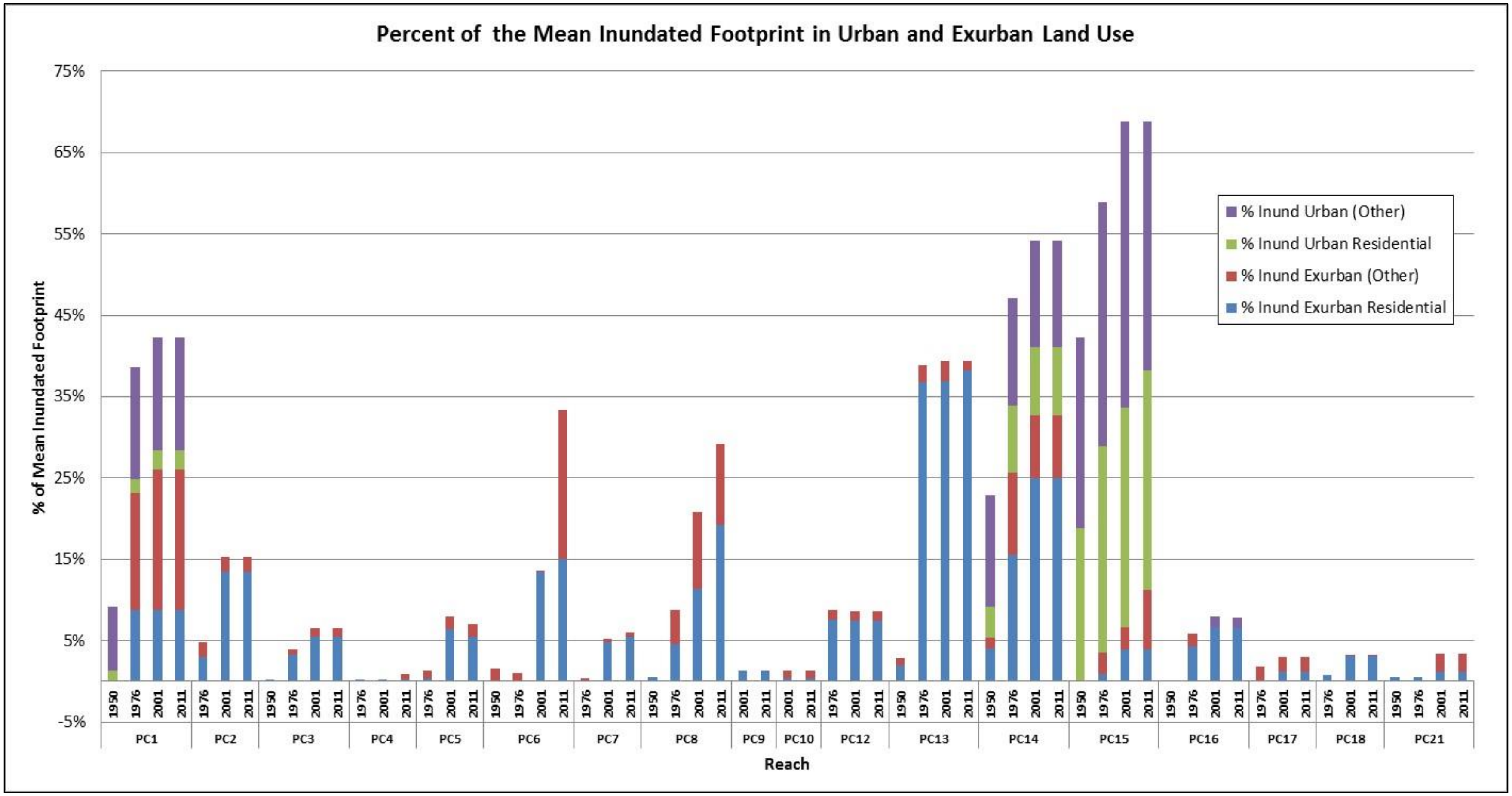


Figure 4-12 Urban and Exurban Land Use Growth in Region PC

Region A is similar to Region PC, in terms of acres of inundation area converted to urban/exurban. That change was from a 1950 total of 100 to 701 acres in 2011, or from 0.5 to 3.4 percent of Region A. The major differences from Region PC include (1) irrigated agricultural land reduction of 1,302 acres, which does not balance out with the gain of 601 acres of urban/exurban land use, and (2) essentially all of the urban/exurban growth is related to the towns in Region A, with the growth increasing downstream. Of the 601 acres total floodplain urban/exurban growth 261 acres occurred around Laurel at the downstream end of the region. No reach in Region A exceeds 21 percent urban/exurban development of its inundation area.

Middle River

Region B extends from the mouth of the Clarks Fork River to the mouth of the Bighorn River, all in Yellowstone County. From a socioeconomic aspect, there is an abrupt end to the upper river land use pattern at Billings. Everything downstream from Billings has land use patterns similar to the lower river and is concentrated on agricultural land use. Billings itself, however, is the largest urban area on the Yellowstone River and also in Montana.

Billings is not only reflective of the dominant river land uses - agriculture and transportation and urban/exurban housing growth - it has achieved its urban status because it is also a city with ties to the oil and gas industry, has a significant medical community, and is a regional retail and convention events center. As such, its growth has far outstripped the rest of the river communities. Keeping in mind that the valley widens as it reaches Yellowstone County, the city was originally centered on the rail line that has its facilities well away from the river. Billings thus extends far beyond the limits of the Total Mapped Area for this study. Even with that setback from the river, urban land conversion at Billings still covers a significant area of the 100-year inundation area. The city has grown steadily over recent census periods, and there is a trend of continuing impingement further into the inundated area and Channel Migration Zone (CMZ) up and down the river.

Billings' urban development now occupies portions of the 100-year inundation area in three river reaches (Reaches B1 through B3). In 1950, only 355 acres of inundation area had been converted to urban use. By 1976, there had been about a 400-percent jump in floodplain conversion to urban use (1,272 acres), and urban conversion has continued to add acres along the inundation area (to totals of 1,623 acres in 2001 and 1,840 acres in 2011). In contrast, Miles City (145 miles to the east in Region C), which is more centered on the river, shows the general pattern in eastern Montana. Miles City occupies two reaches of Region C, C16 and C17. In 1950, urban use of the inundated area totaled 1,150 acres; in 2011 that had only grown to 1,337 acres.

Livingston, located along the Upper Yellowstone in Reaches PC 14 through PC16, while exhibiting growth expected in a community that is in a growing tourist and amenity landscape, saw urban use change from 264 acres in 1950 to 361 acres 61 years later in 2011. Clearly, Billings is the community on the river that has affected more acres and more miles of the river. Billings continues to show the characteristics that has caused its growth from its beginnings: transportation hub, agriculture center for equipment and crop processing, regional retail center, ever growing medical center, and though periodic, center for support facilities relating to mineral development.

All three of the Billings reaches have shown tremendous growth over the length of the study period within the inundated area. In 1950, both Reaches B1 and B3 urban and exurban areas occupied less than 5 percent of their reaches. By 2011, those same reaches had urban/exurban occupation of 20 and 32 percent, respectively, and both showed a continued steep upward growth curve. In Billings itself, the urban growth curve was even steeper, and urban/exurban development had grown from 25 percent of the inundation area in 1950 to 74 percent in 2011.

Near Billings, there has been an extraordinary amount of incursion into the CMZ of the Yellowstone River in Reaches B1, B2, and B3. The three reaches show a similar growth curve to the same three reaches in the inundation area. Reach B1 had moved from exurban occupation of about 1 percent of the reach in 1958 to about 9 percent in 2011. However, other development land uses like transportation and agricultural infrastructure bring that total up to about 16 percent.

Reach B2 shows the greatest growth rate and incursion into the CMZ. Urban and exurban conversion of CMZ acres was about 12 percent in 1950. That total rose to 44 percent in 1976, with most of the conversion moving from exurban to urban. Associated transportation added 2.5 percent to that total. All development was either urban or transportation in Reach B2, and the incursion into the CMZ had grown to 40 percent of the reach. Change occurred even more quickly in the ten years between 2001 and 2011, and occupation of the CMZ increased to 88.5 percent. Very little native vegetation or habitat remained in Reach B2 by 2011.

Below Reach B4 the valley rapidly becomes largely agricultural because of the presence of the Bureau of Reclamation Huntley Irrigation Project. However, there are three communities associated with the project as well as some small exurban carve-outs within the irrigation project. Nevertheless, by the east end of Huntley, just six miles east of Reach B3, urban and exurban development has nearly disappeared. The lower B reaches show the dramatic change from urban and exurban land use in the inundation area to agricultural land use. Similar to the other lower river regions, the agricultural land use category stays stable or grows between 1950 and 2011. See Figure 4-13 to view the percentage growth in Region B.

Lower River

The lower two regions (C and D) experienced little urban expansion between 1950 and 2011. Glendive is something of an anomaly, having grown from 39 acres of urban development in the 100-year inundated area to 329 acres between 1950 and 1976, and then slowed, with an increase only to 414 acres through 2011. This is almost certainly due to the routing of Interstate Highway 94 completed in the 1960s, which skirted the floodplain to the west of Glendive, until it reached a point just north of the city, and then turned east to cross the river. The massive and extended twin-graded fill used to meet the elevation of the bridge cut off a Yellowstone River side channel and effectively provided a protective dike on the north side of the city. That completed protection of the floodplain on all sides as a levee to the east and an elevated railroad grade and valley highlands to the west and south protect other areas of Glendive's immediate floodplain from flood waters. After completion of the Interstate, almost 300 acres of urban expansion occurred, mainly in industrial and commercial development.

Miles City is typical of eastern Montana. The 1,177 acres its urban area encompassed within the study area in 1950 remained nearly static through 2011 at 1,212 acres, influenced only slightly by interstate highway access points to the west and south of the city. Forsyth, the other community of any size that is located adjacent to the river, follows much the same pattern. In 1950, its urban area covered 484 acres rising moderately to 728 acres in 2011. Its role as a coal train make up and crew division point probably accounts for its expansion.

Forsyth, Miles City, and Glendive comprise 2,781 of the 3,250 acres of urban/exurban development in the 100-year inundated area in 2011. In these lower river C and D regions, urban development accounted for only 4.1 percent of the inundated area. (Note: The data for this section were last collected in 2011 and do not reflect the growth occurring in northeastern Montana as a result of the Bakken oil development.)

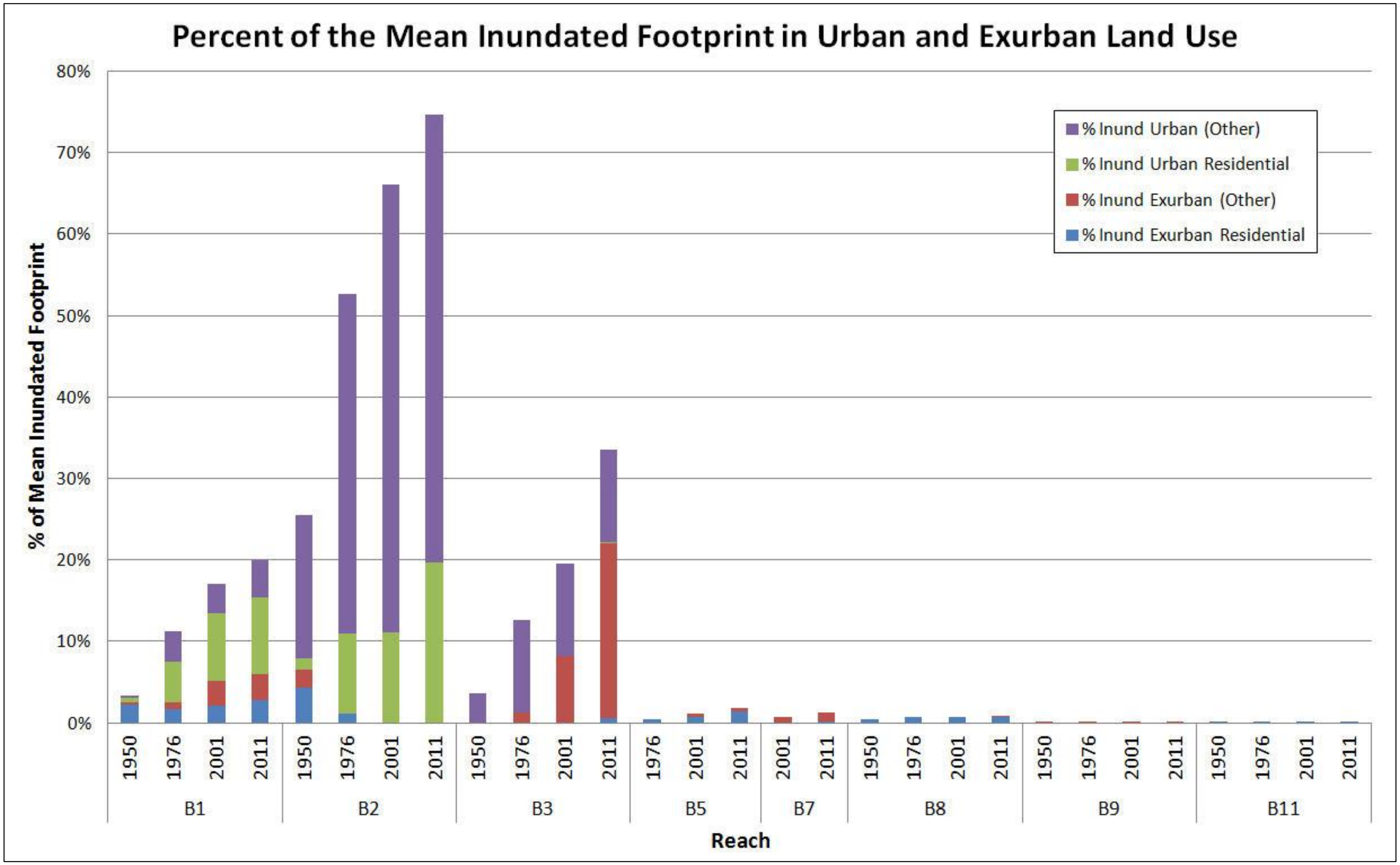


Figure 4-13 Urban and Exurban Land Use Growth in Region B

Exurban development in the 100-year inundated area is hardly discernible for Regions C and D, even in 2011. From a base of 122 acres in 1950, which is less than 0.1 percent of the floodplain, there was steady but small growth through the next 60 years. In 2011, the exurban acreage was 834 acres for these regions, which is still only approximately 0.5 percent of the inundation area.

4.2.4.5 Off-Corridor Impacts

Off corridor land use decisions have some influence on the river corridor, but have not been specifically or regionally measured except in the case of irrigated agricultural activities' water withdrawals, which are cumulatively measured at the points where the significant tributaries intersect with the mainstem of the river in Montana.

From up-river to down, the following is a list of off-river land uses that have at least indirectly affected the Yellowstone River and valley:

1. Yellowstone National Park. The national park presently attracts about 3 million visitors per year. With similarities in scenery and comparable trout fishing to the national park, the river vicinity has attracted permanent residents and second-home owners in the Yellowstone Valley at least as far downstream as Regions PC and A.

2. Irrigated agricultural land. Irrigation off the mainstem adds to the total of water withdrawals on the mainstem. These withdrawals are measured only as the tributaries enter the mainstem, and thus are accounted for as a single amount for each tributary where the effect is great enough to be measurable in the Yellowstone River numbers. See Section 1.1.1.1 for an analysis of the effect of irrigation withdrawals.

3. Yellowtail Dam. This dam is the first dam upstream of the Yellowstone on the Bighorn River and is one of three large upstream dams. As it controls the entire flow of the Bighorn at its location and has flood control and hydroelectric power as its major purposes, it has a significant effect on river flows and water quality below the Bighorn/Yellowstone confluence. See Section 4.3 for an analysis of dam-caused changes to river Hydrology.

4. Tongue River Dam and Reservoir. This dam is located 178 miles upstream from the Yellowstone and is used primarily to store irrigation water for downstream users. Its effect on the Yellowstone is seen in the analysis of water withdrawals in the Hydrology and Hydraulics sections.

5. There are significant open pit coal mines that serve four coal-fired electric power plants at Colstrip, Montana, south of Forsyth. These plants withdraw water from the Yellowstone for cooling and processing purposes. Withdrawals are analyzed in the Hydrology and Hydraulics sections.

6. After 2011, major use of hydraulic fracturing in oil and gas extraction had begun to create demand for water withdrawals in the Bakken oil field of northeast Montana and northwest North Dakota. Those water demands have not been addressed in this study, as they occurred after the final data collection point of 2011.

4.3 Hydrology

The following chapter summarizes the effects of human development on the hydrology of the Yellowstone River. A summary of the analyses performed in this investigation is contained in Appendix 2 (Hydrology).

4.3.1 General Hydrologic Setting

The hydrology of the Yellowstone River is sustained by the drainage of about 71,000 square miles of watershed area in Montana and Wyoming. The watershed is strikingly asymmetric; all of the river's major tributaries enter from the south including the Boulder, Stillwater, Clarks Fork, Bighorn, Tongue, and Powder rivers. Most of these rivers originate in Wyoming and flow north to join the Yellowstone (Figure 4-14).

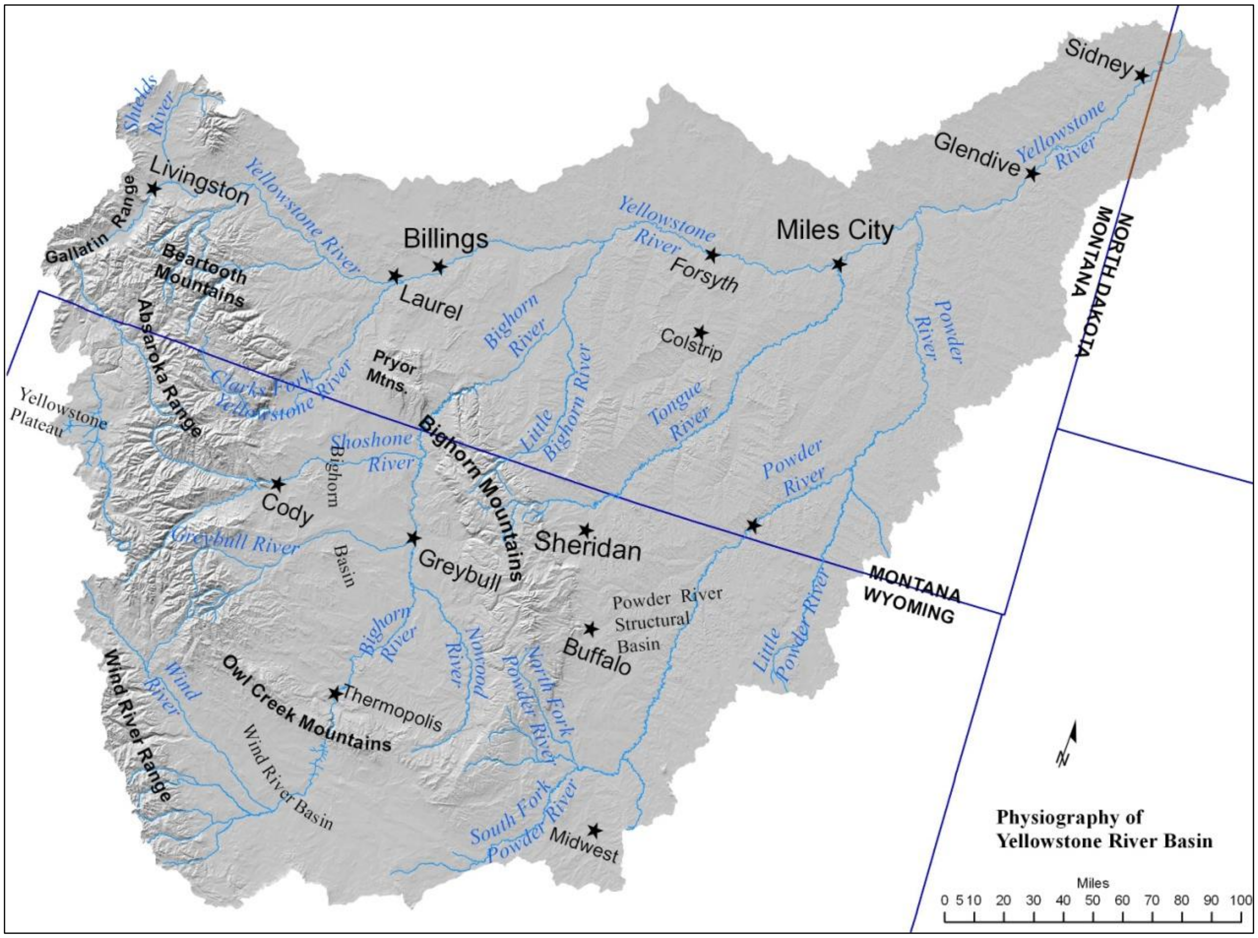
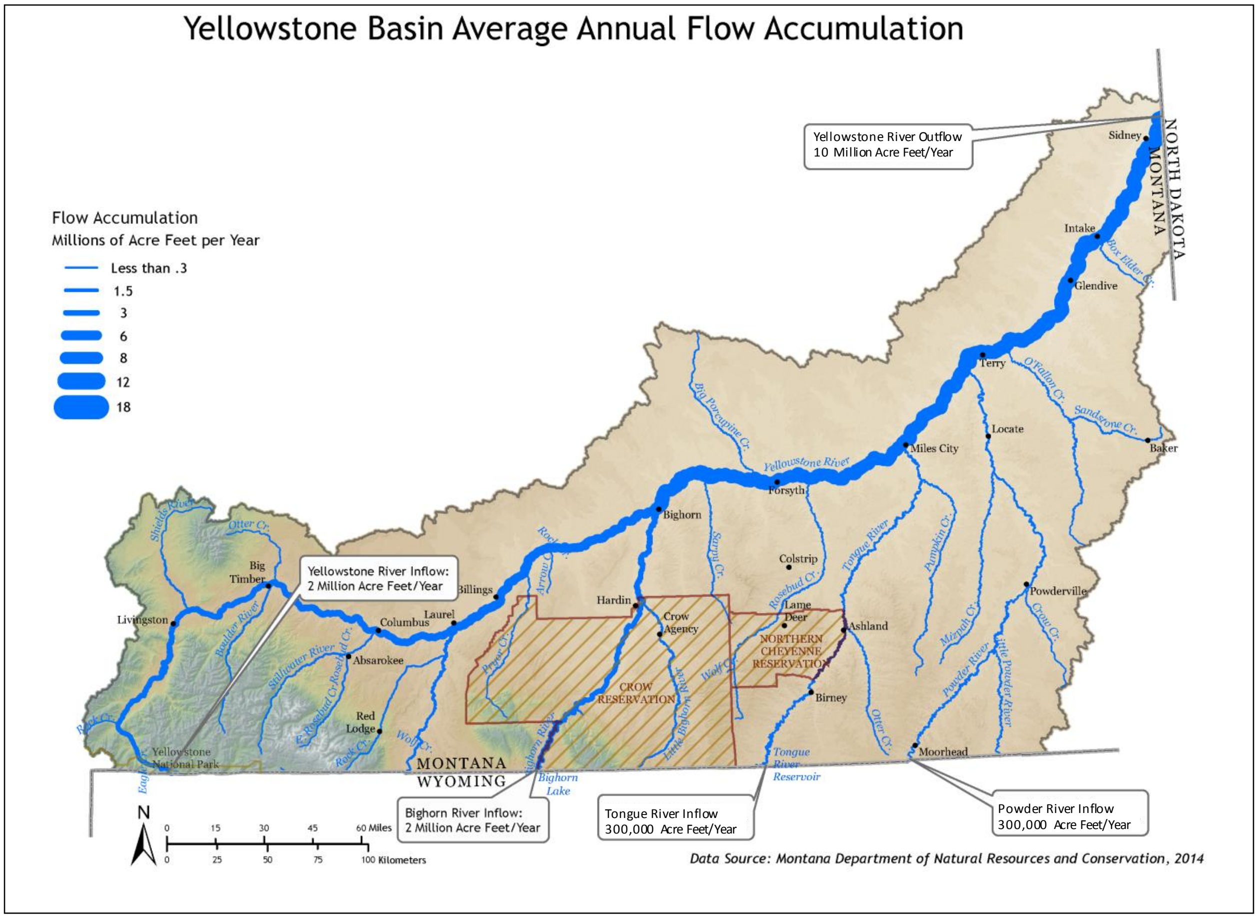


Figure 4-14 Physiography of the Yellowstone River Basin (Montana DNRC, 2014)

The average annual volume of water measured leaving the basin at Sidney is about 7.7 million acre-feet. It has been estimated that about 2.4 million acre-feet of water are consumed in the basin every year, such that the total volume produced in the watershed is about 10 million acre-feet of water per year (Montana DNRC 2014). Of that 10 million acre-feet, 4.6 million acre-feet originates in Wyoming Figure 4-15).



Source: Montana DNRC, 2014

Figure 4-15 Average annual flow accumulation of the Yellowstone River and its major tributaries

4.3.1.1 Yellowstone River Flood History

The Yellowstone River is capable of producing extreme floods both due to snowmelt driven runoff in the upper basin and individual storm events in the plains segments of the lower watershed. Ice jam–related flooding is also common. As such, it is uncommon to have a single flood affect the entire river. Since the early 1940s, the only years that every stream gage on the mainstem Yellowstone recorded an event in excess of the 10-year flood are 1943 and 2011 (Figure 4-16 and Table 4-1). In 1943, however, the high flows in the lower river at Sidney occurred in March, and the high flows in the upper river peaked in June, indicating two discrete flood events. During the spring 2011 flood, all of the mainstem and tributary gage records, with the exception of the Bighorn River at St Xavier, exceeded the 10-year event. Even that event was spatially complicated however; the Tongue and Powder Rivers peaked in late May and the upper basin peaked in late June. The 2011 flood was especially notable for both its magnitude and its duration; at many locations the 10-year flood discharge was exceeded for weeks. The 2011 flood was the peak flow of record at Livingston, exceeding a 100-year event (40,600 cfs on June 30). At Miles City and Sidney, the 2011 flood was between a 10- and 25- year event.

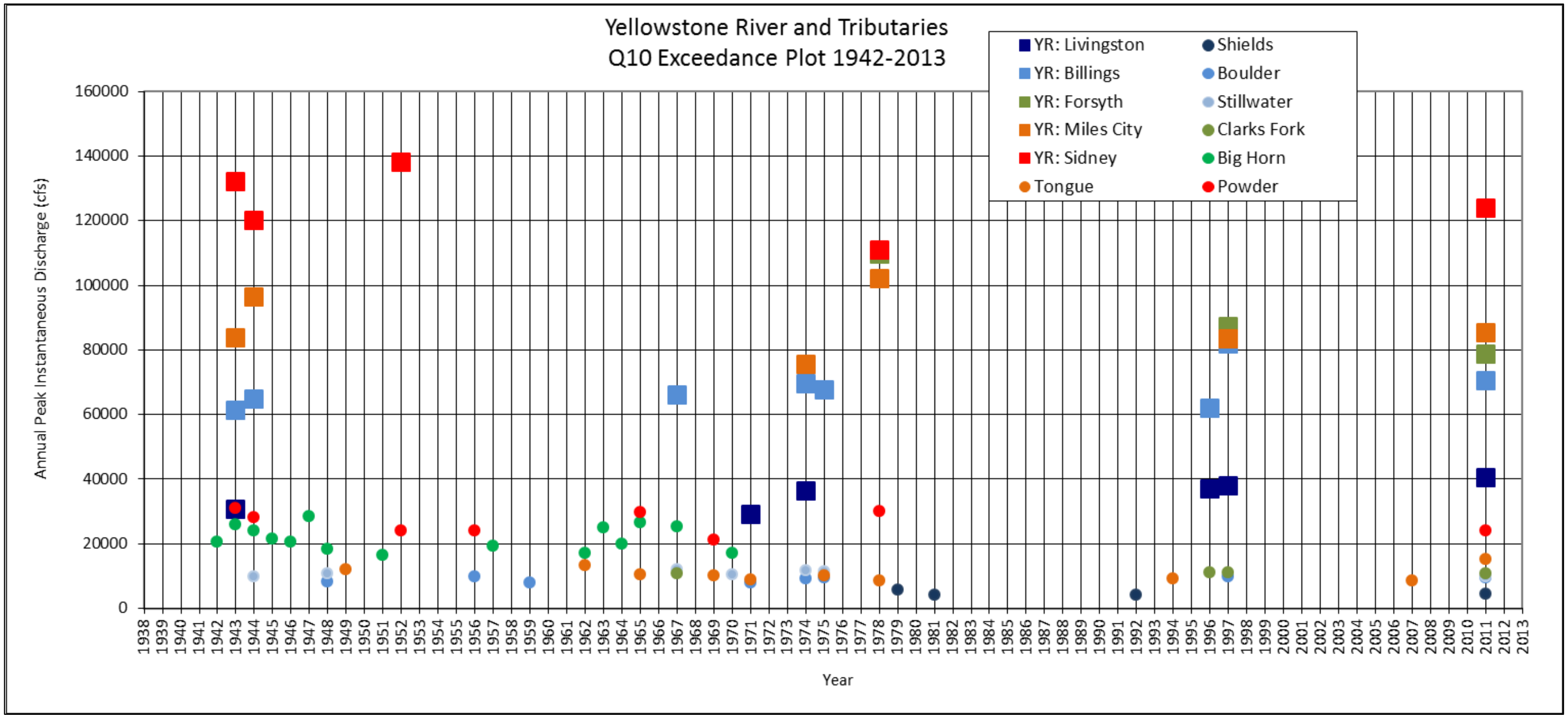


Figure 4-16 Flood events with discharges exceeding a 10-year return interval, Yellowstone River corridor

Table 4-1
Yellowstone River Major Flood History

Year	Flood Frequency at Livingston	Flood Frequency at Miles City	Flood Frequency at Sidney	Tributaries Flowing at >10 year event	Primary Area of Flooding
1943	Q10-Q25 (30,600 cfs on June 20)	Q10-Q25 (83,700 cfs on June 26)	Early season Q25-Q50 (132,000 on March 29)	Bighorn	Two floods; March in lower river and June in upper river
1944	<Q10	Q50-Q100 (96,300 cfs on June 19)	Q10-Q25 (120,000 on June 21)	Stillwater, Powder, and Bighorn	Billings and Lower
1952	< Q10	< Q10	Q25-Q50 (138,000 cfs on March 31)	Powder	Sidney
1967	< Q10	< Q10	< Q10	Stillwater, Clarks Fork, Bighorn	Billings
1971	Q10-Q25 year event (29,200 cfs on June 23)	< Q10	< Q10	Boulder, Tongue (Feb)	Livingston
1974	Q50-Q100 (36,300 cfs on June 17)	Q10-Q25 (75,400 cfs on June 22)	< Q10	Boulder, Stillwater	Livingston to Miles City
1975	< Q10	< Q10	< Q10	Boulder, Stillwater, Tongue	Billings
1978	<10 year event	Q50-Q100 (102,000 cfs on May 22)	Q10-Q25 (110,000 cfs on May 23)	Tongue, Powder	Forsyth to Sidney
1996	Q50-Q100 (37,100 cfs on June 10)	< Q10	< Q10	Clarks Fork	Livingston to Billings
1997	Q50-Q100 (38,000 cfs on June 6)	Q10-Q25 (83,300 on June 15)	< Q10	Boulder, Clarks Fork	Livingston to Miles City
2011	Q100 (40,600 cfs on June 30)	Q10-Q25 (85,400 cfs on May 24)	Q10-Q25 (124,000 cfs on May 24)	Shields, Boulder, Stillwater, Clarks Fork, Tongue, Powder	River-Wide

4.3.1.2 Ice Jams and Associated Flooding

Ice jam information was retrieved from the U.S. Army Corps of Engineers Ice Jam Database that is housed by the Cold Regions Research and Engineering Laboratory in New Hampshire (http://icejams.crrel.usace.army.mil/). These records indicate that over 100 ice jams have occurred on the Yellowstone River since the late 1800s. These ice jams have caused infrastructure damage, flooding, and loss of life and property (Figure 4-17 and Figure 4-18). Similar to flooding, the ice jam history on the Yellowstone may play an important role in interpreting human impacts within the river corridor, as areas most prone to ice jamming have land use challenges that are different than those where ice jams are rare. Also, certain human impacts, such as bridges, may result in flow constrictions and a higher propensity for ice jamming.

Figure 4-17 Ice remnants on floodplain at Glendive, 2014

Figure 4-18 Ice action at Intake Diversion Structure, 2014

On the Yellowstone River, only three reaches have more than ten reported ice jams (Figure 4-19). These reaches include Reach C16, Reach D6, and Reach D13. Reach C16 is located at Miles City. Descriptions of the Miles City ice jams include gage height measurements that reflect backwatering from ice (DTM and AGI 2008), descriptions of flooding on the Tongue and Yellowstone Rivers, levee damage, and large scale evacuations. The majority of ice jams at Miles City occurred in March. One ice jam that occurred at Miles City on March 20, 1944, was bombed by planes in an effort to break up the jam (DTM and AGI 2008). Reach D6 is located at Glendive, where ice jams have developed during the months of December, January, February, March, and April (Figure 4-19). One of the most damaging ice jams happened in Reach D6 at Glendive in 1899, where three bridges were destroyed and 12 people died.

Both the Tongue and Powder Rivers have over 20 recorded ice jams, most of which developed during the month of March (Figure 4-19).

The stream gage at Sidney recorded three floods during the month of March that exceeded a 10-year flood event and may have been related to ice jamming. These floods occurred in 1912, 1943, and 1952.

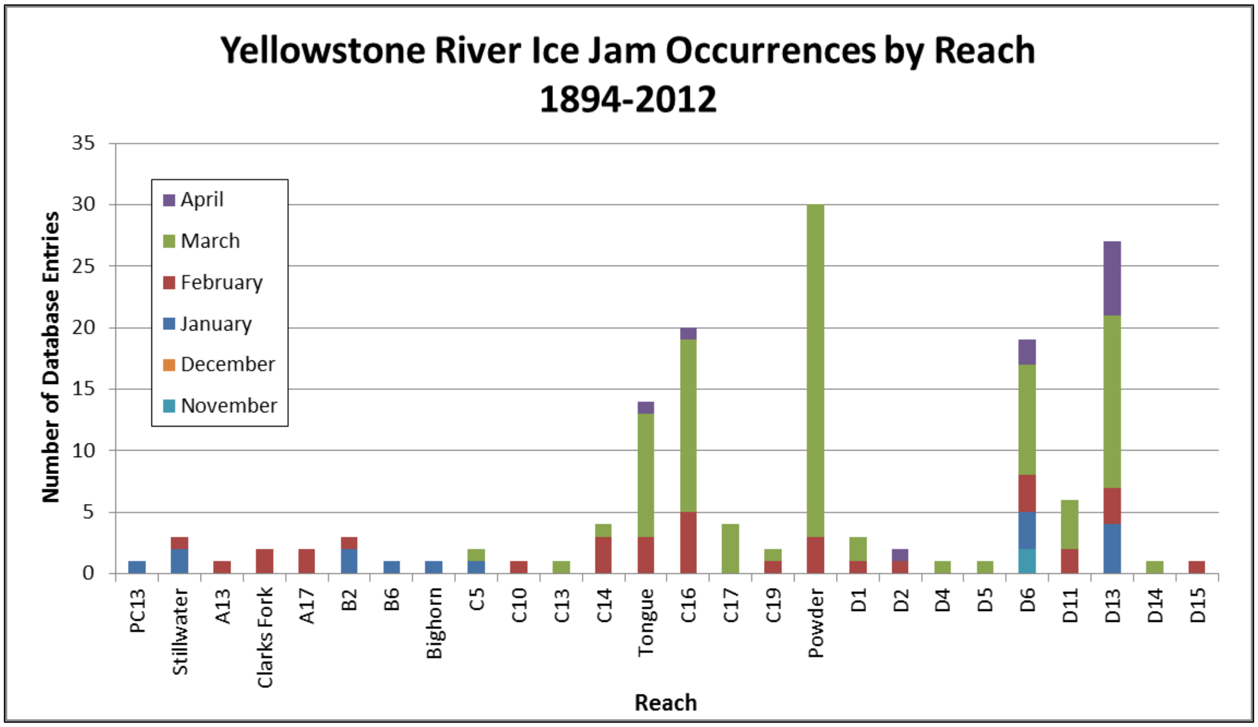


Figure 4-19 **Number of ice jam database entries for reaches of the Yellowstone River and selected tributaries**

Note: *Multiple entries may exist for a single event*

4.3.1.3 Major In-Stream Diversion Structures

Over the past century, numerous diversion structures have been built on the Yellowstone River to support irrigation. These irrigation diversions composed of rock or concrete typically block or partially block the main channel. There are also several large pump stations on the channel banks and dozens of small pumps and headgates that support irrigation activities. All of these features, as well as tributary structures, affect the hydrology of the Yellowstone River.

Between Billings and Sidney, a total of six irrigation diversion dams cross the Yellowstone River. These dams include Huntley, Waco-Custer, Rancher’s Ditch, Yellowstone, Cartersville, and Intake (Table 4-2 and Figure 4-20,).

Table 4-2
Summary Information for Six Major Irrigation Diversions between Billings and Sidney

Name	Location	Reach	Crest Length (feet)	Diversion Capacity (cfs)	Date Completed
Huntley Dam	Huntley	B4	325	600	1934
Waco-Custer	W of Custer	B9	210	125	1907
Rancher's Ditch	Downstream of Bighorn R. confluence	C1	1,040	No data	1904
Yellowstone Ditch	W of Hysham	C3	660	No data	1909
Cartersville	Forsyth	C10	800	No data	1934
Intake Diversion	Downstream of Glendive	D8	700	1,200	1911

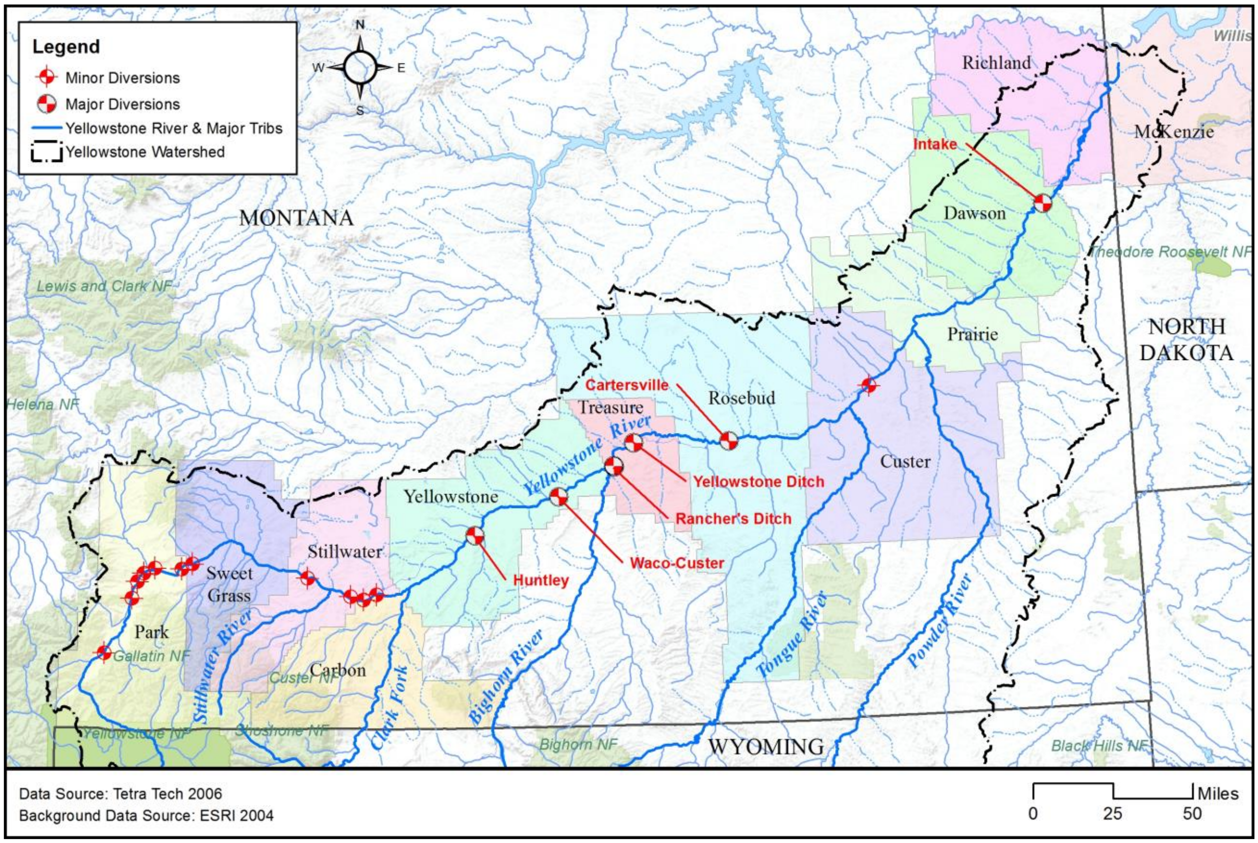


Figure 4-20 Major and Minor Instream Diversions, Yellowstone River

The uppermost and lowermost structures (Huntley and Intake) are federally owned, whereas the middle four are privately owned and managed by local irrigation districts. All six of these major irrigation structures are fish passage barriers to some extent. However, the degree to which each structure impedes passage depends on river stage and the swimming ability of the various species trying to negotiate the structures (USFWS, 2008)

Huntley

Huntley Diversion Dam is located approximately two miles upstream of Huntley (Figure 4-21). The structure feeds a 32 mile long main canal, trends easterly, and irrigates a strip of land ranging from one to four miles wide (DTM and AGI 2008). 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.

Figure 4-21 Aerial image (2005) of Huntley Diversion Dam prior to installation of the fish passage channel.

The Huntley diversion structure was originally constructed as a temporary earth-fill 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 2011 flooding, a fish passage channel was constructed around the north end of the dam. After the 2011 Silvertip Pipeline spill upstream of Billings, the Montana Department of Environmental Quality (MDEQ) required Exxon Mobil to pay fines which were then used to improve the bypass channel. The 2011 flood also severely damaged the Huntley Canal downstream of the dam where it crosses Pryor Creek (Figure 4-22); subsequent reconstruction of the crossing as a syphon has restored fish passage in to Pryor Creek for the first time in 100 years (Figure 4-23; AGI and CCI 2012).

Waco-Custer

The Waco-Custer ditch company was formed in the early 1900s, and the diversion dam was constructed shortly thereafter (DTM and AGI 2008). 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 (Figure 4-24). The structure feeds the Waco-Custer Canal, which flows on the south side of the river.

Figure 4-22 View of active flanking of Huntley Canal tunnel by Pryor Creek during 2011 flood

Figure 4-23 View downstream of lower Pryor Creek towards Yellowstone River, showing creek passing over newly constructed Huntley Canal siphon, which passes under creek from left to right below riprapped banks

Note: Crossing has restored fish passage into Pryor Creek watershed for first time since early 1900s

Figure 4-24 Aerial image of Waco-Custer Diversion Dam (2005)

Rancher's Ditch

The Rancher's Ditch diversion dam is located approximately 2.5 miles downstream of the Bighorn River confluence (Figure 4-25). The dam was constructed in the early twentieth century and feeds a canal that flows on the north side of the Yellowstone River. The diversion capacity of Rancher's Ditch diversion was not available. 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. There is a small channel through the island that is not blocked by the dams. Repairs to the dam following the 2011 flood included increasing the crest height which may have reduced fish passage at the structure.

Yellowstone Ditch

The Yellowstone Ditch Diversion Dam is located west of Hysham at River Mile 282 (Figure 4-26). The structure was built in 1909. At the diversion, the Yellowstone River flows within a single thread. However, the channel segment upstream of the bridge that extends to Myers Bridge is characterized by multiple anabranching channels that form large, vegetated islands.

Cartersville

Cartersville Dam, constructed in the early 1930s at Forsyth, consists of a rock rubble riprap core that is capped by concrete (DTM and AGI 2008). The structure is 800 feet long, spanning the width of the Yellowstone River (Figure 4-27 and Figure 4-28). The river flows within a single thread at the structure, flowing along the northern bluff line of the river valley. The city of Forsyth is located on the opposite (southern) bank. Because of its impacts on the Yellowstone River fishery, efforts have begun to develop suitable alternatives and bypass designs to promote fish passage at Cartersville (DOWL HKM et al. 2010).

Figure 4-25 Aerial image of Rancher's Ditch Diversion Dam (2005)

Figure 4-26 Aerial image of Yellowstone Ditch Diversion Dam (2005)

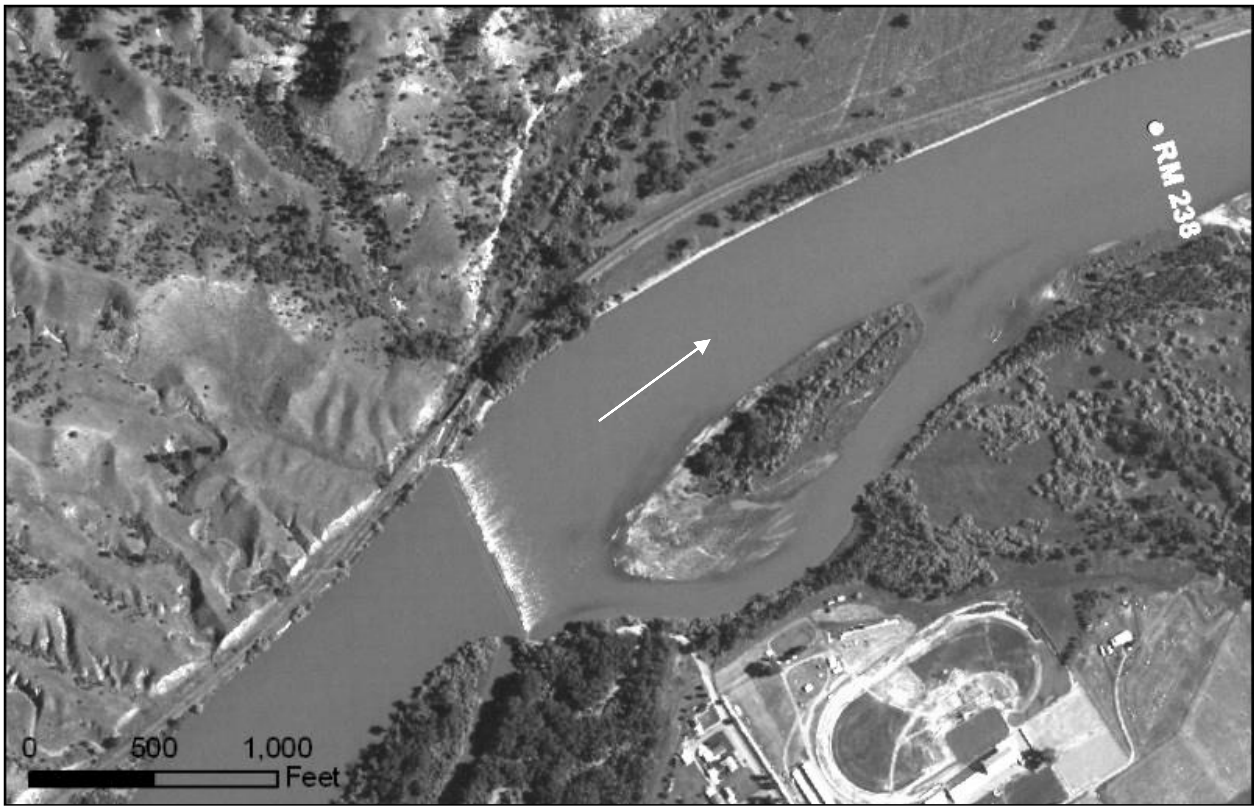


Figure 4-27 Aerial image of Cartersville Diversion Dam (2005)

Figure 4-28 View north of Cartersville Diversion Dam

Intake

The largest diversion dam on the Yellowstone River is Intake (Figure 4-29). Construction of the dam began in 1905, in response to authorization under the Reclamation Act of 1902 (DTM and AGI 2008). Intake Dam was completed in 1911 and is used to irrigate 50,000 acres of land in eastern Montana and western North Dakota. The original dam crest was 12 feet above the river bed and the structure stretches 700 feet across the river (Figure 4-30). With a diversion capacity of 1,200 cfs, it feeds Intake Canal and a ~225 mile network of lateral canals that distribute water to approximately 500 farms. Previous studies had indicated that approximately 500,000 fish were being entrained into the main irrigation canal annually (USBOR). Prior to the 2012 irrigation season, the diversion headworks were reconstructed with fish screens (Figure 4-31). Fish passage issues at this structure are currently being addressed by the Bureau of Reclamation, U.S. Army Corps of Engineers, Montana Fish Wildlife and Parks, U.S. Fish and Wildlife Service, and Lower Yellowstone Irrigation District.

4.3.1.4 Buffalo Rapids Project (Pumping Plants)

In addition to diversion dams, irrigation pumps are extensively utilized on the Yellowstone River. The largest of these pumping systems is the Buffalo Rapids Project, which consists of six pumping plants and 63 miles of canals; these plants and canals provide irrigation water for 22,719 acres of land in the vicinity of Glendive, Fallon, and Terry (USBR, 2015). The Fallon Pumping Plant, with a diversion capacity of 72 cfs, is located approximately 3 miles east of Fallon and was constructed from 1946 to 1948. The Shirley Pumping Plant is located approximately 20 miles southwest of Terry and has a capacity of 111 cfs. The Glendive Pumping Plants (No. 1 and No. 2) is located near Fallon and has a total diversion capacity of 368 cfs. The Terry Pumping Plant, with a diversion capacity of 60 cfs, is located approximately 6 miles east of Terry.

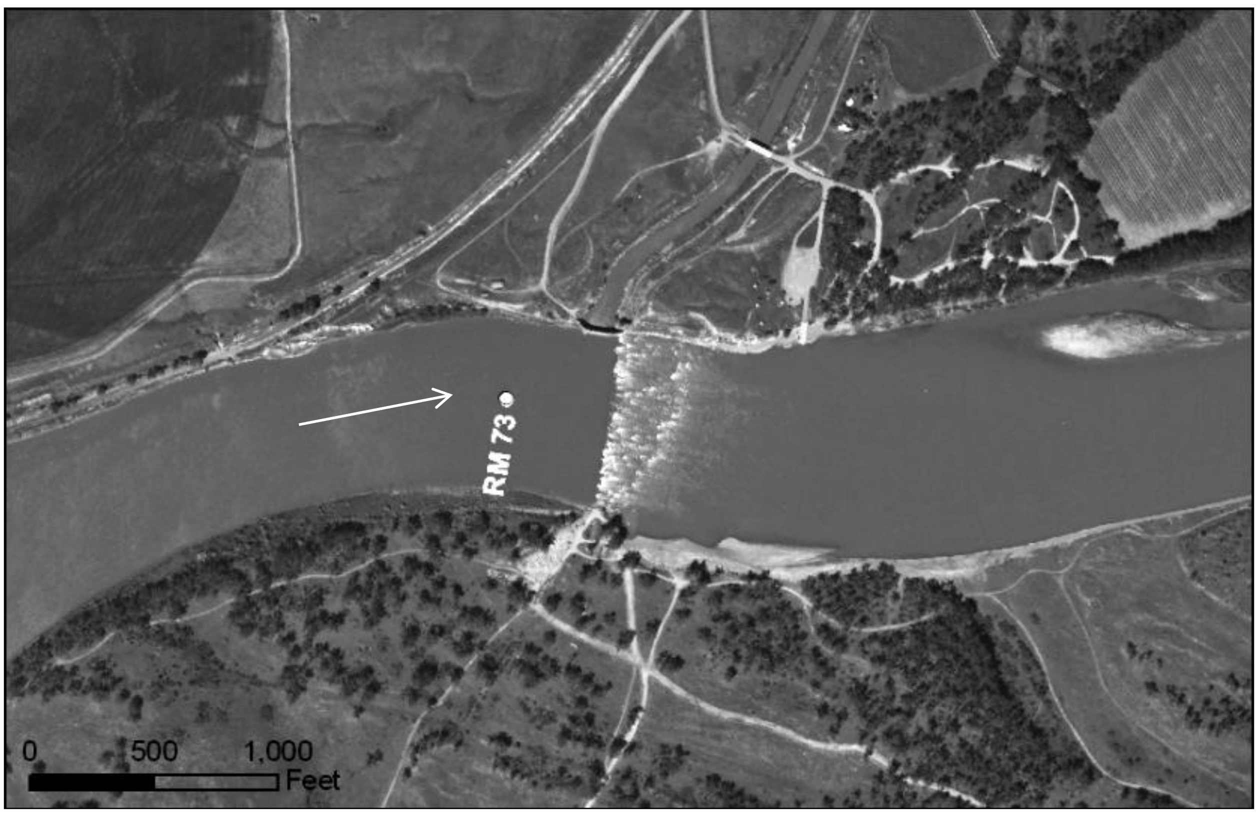


Figure 4-29 2005 aerial image of Intake Diversion Dam

Figure 4-30 Intake Diversion Dam showing old headworks (USBOR)

Figure 4-31 New headworks with fish screens, Intake Diversion (USBOR)

4.3.1.5 Small Irrigation Pumps and Diversions

The 2001 physical features dataset for the Yellowstone River (NRCS 2001) includes 211 mapped features: headgates (26), irrigation diversions (19), portable irrigation pumps (98), and permanent pumps (68). These irrigation structures are distributed throughout the basin, with an increased abundance of portable pumps in the lower river (Figure 4-32). Small diversions span side channels that carry a disproportionately small amount river flow.

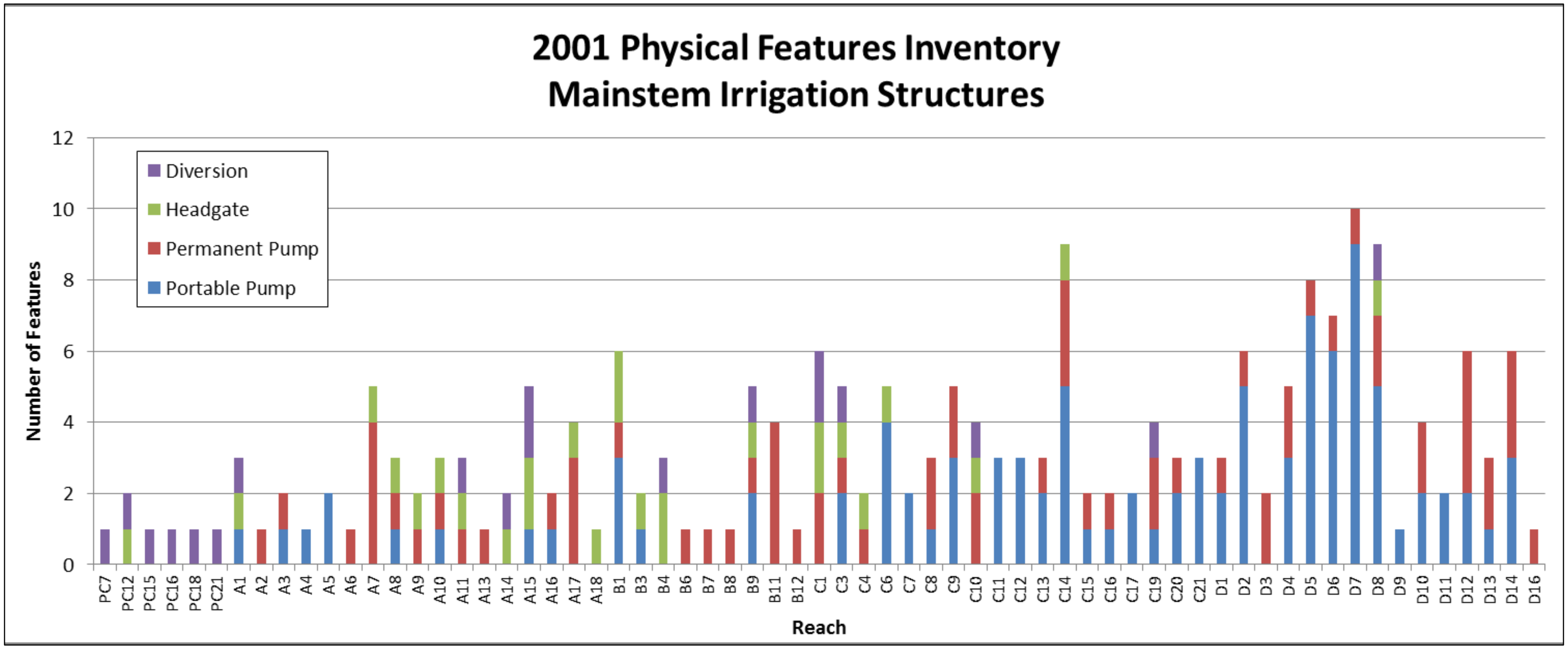


Figure 4-32 Number of mapped 2001 irrigation structures on mainstem Yellowstone River by reach

4.3.1.6 Bighorn River Flood Control Structures

There are three major dams on the Bighorn River. Yellowtail Dam is a 525 foot high concrete thin arch structure that was built on the Bighorn River in the mid-1960s (Figure 4-33; USBR, 2015a). The dam is located approximately 96 valley miles upstream of the Yellowstone River confluence at Bighorn. The total capacity of Bighorn Lake is 1,331,725 acre-feet, and it is the largest reservoir in the Bighorn River watershed. Upstream of the lake, the Bighorn River watershed is largely within the state of Wyoming where it encompasses 23 percent of the state's total area. The structure is a 1,480 foot-long concrete arch that has a structural height of 525 feet. The dam is the highest dam in the Missouri River Basin and was constructed for power generation, irrigation, flood control, and recreation. Operating guidelines and targets for the structure include satisfying senior water rights, water contract commitments, providing adequate storage space to safely store spring runoff and provide flood control, and power generation. Flood control targets include preventing flows at the confluence with the Yellowstone River from exceeding 25,000 cfs.

Source: www.usbr.gov

Figure 4-33 Yellowtail Dam construction, 1963-1966

The two other large reservoirs in the basin include Boysen Reservoir south of Thermopolis and Buffalo Bill Reservoir near Cody. Buffalo Bill Dam was built on the Shoshone River six miles upstream from Cody Wyoming in 1910. It has a capacity of 650,000 acre feet. Boysen Dam was constructed between 1947 and 1952 on the Wind River approximately 17 miles south of Thermopolis, Wyoming. Boysen and Buffalo Bill Reservoirs have capacities of 745,851 acre-feet and 644,540 acre-feet, respectively (www.waterplan.state.wy.us). These two reservoirs collectively impound about the same amount of storage provided by Yellowtail Dam, which was completed in 1967 and stores about 1.4 million acre feet. In considering hydrologic alterations, Buffalo Bill Dam may have already impacted Yellowstone River flows by 1910 prior to the availability of stream gage data. Buffalo Bill Dam was also raised significantly in the late 1980's to increase storage. Boysen Reservoir was completed in 1952. Both of these reservoirs are upstream of Yellowtail Dam. The estimated maximum annual net evaporative loss for all three reservoirs combined is 116,191 acre-feet.

There are also several diversion dams on the Bighorn River below the Yellowtail Dam afterbay structure which have been identified as potentially entraining fish and reducing passage.

4.3.2 Major Findings in Support of Cumulative Effects Analysis

The overall goal of the hydrologic analysis is to provide a general summary of changes in streamflow within the mainstem of the Yellowstone River due to human development. The primary information sources are described in Appendix 2 (Hydrology) which should be accessed for a more complete summary of the results.

4.3.2.1 Comparison of Regulated and Unregulated Flows

In order to estimate the impacts of human development on streamflow, a major study was performed as part of the CEA to compare pre- and post- development streamflow conditions on the mainstem Yellowstone River (Corps of Engineers 2011; Chase 2013, 2014). The hydrologic study consisted of the evaluation of water depletions in the system to develop flow statistics for both an Unregulated (Undeveloped) and Regulated (Developed) flow condition. The comparison of these flow statistics allows some estimation of changes in typical flow volumes (e.g., 100-year flood), under pristine watershed conditions and under modern, developed conditions. The change in these flows can then be investigated in terms of the likely cause of that change.

The methodologies used in the USGS and Corps hydrologic analyses are described in detail in the original reports (Corps of Engineers 2011; Chase, 2013; and Chase, 2014). The approach basically used depletion data to develop two flow records: 1) no depletions (unregulated), and 2) with modern depletions (regulated). These constructed flow records were then analyzed to develop flow statistics for each condition, to help define the impacts of human development on Yellowstone River hydrology.

The main analysis is a comparison of the hydrology of the river under "unregulated" and "regulated" flow conditions, defined as the following:

- Unregulated: Flow statistics for a hydrologic record for which the effects of streamflow regulation have been removed; and,

- Regulated: Flow statistics for a hydrologic record that has been adjusted to represent near-present day (based on 2002) levels of development.

For the purposes of the Cumulative Effects Study, Unregulated flows can be considered to represent an undeveloped condition, whereas Regulated flows reflect the modern developed condition.

The objective of the analysis is to determine how flow conditions have changed on the Yellowstone River due to human development, and to use that information to help interpret the causes of observed changes in other aspects of river condition, such as extent of floodplain access, river size, erosion rates, water quality, and riparian vegetation dynamics.

The regulated/unregulated flow analysis included an interpolation of results from gaging stations to reaches. Appendix 2 (Hydrology) contains a summary of the methodology and limitations associated with that interpolation.

A comparison of the Regulated and Unregulated flow statistics revealed the following primary findings (Appendix 2 (Hydrology)):

- Bighorn River flow alterations have exerted a major influence on the hydrology of the lower Yellowstone River. These flow alterations on the Bighorn River are due to reservoir operations and Bighorn basin irrigation.

- Irrigation-related water use on the Yellowstone River mainstem and other tributaries has also contributed to changes in flows on the river. Irrigation in the Clarks Fork basin has had a relatively substantial influence on Yellowstone River flows.

- A comparison of the flow statistics indicates that peak flows on the Yellowstone River have decreased for the 2-, 10- and 100-year floods with human development.

- The 1 percent exceedance probability event ("100-year discharge") has dropped by approximately 20,000 cfs below the mouth of the Bighorn River, a 16 percent reduction in total flow.

- The magnitude of the 2-year flood has dropped by approximately 23 percent downstream of the mouth of the Bighorn River. This result is important in that the 2-year flow has a strong influence on overall channel form. Flows estimated as the "channel forming flow" have dropped by about 25 percent.

- Base flows during fall and winter have increased up to 60 percent downstream of the Bighorn River confluence.

- Spring and summer base flows have been reduced by over 20 percent under regulated conditions.

- The lowest flows experienced in the summertime (Summer 7Q10; the lowest 7-day average flow expected to occur every 10 years) have dropped throughout the system, and the relative reduction of those flows increases in the downstream direction. These low flows have dropped by approximately 1,000 cfs (30 percent) at Billings and 1,800 cfs (40 percent) at Miles City.

4.3.2.2 Indicators of Hydrologic Alteration

In order to further consider the impact of Yellowtail Dam on Yellowstone River streamflows, gage records were evaluated using an "Indicators of Hydrologic Alteration" assessment tool that allows users to compare pre- and post-dam flow conditions (The Nature Conservancy 2009). The results of this analysis indicate the following, which directly supports the Unregulated/Regulated flow comparisons described above:

- Flow alterations on the Bighorn River have resulted in a reduction of flood magnitudes on the Yellowstone River below the confluence.

- Yellowtail Dam release patterns have "dampened" the hydrograph on the Yellowstone River by reducing daily rates of discharge rise and fall.

4.3.2.3 Evaluation of Gage Records

An evaluation of gage records at Sidney indicates that hydrologic alterations on the Yellowstone River include both a reduction in peak spring runoff magnitudes and a loss of the definition of the early spring pulse runoff, which tends to occur in late March to early April.

4.3.2.4 Evaluation of Irrigation Water Use

Previously published estimates of water use indicate that irrigation is the dominant water use in the basin (USGS 2004).

Mean monthly flow patterns at Billings are consistent with hydrologic influences of irrigation; analysis of depletions below the Bighorn River indicate that during the winter months, over 80 percent of the increase in low flows is estimated to be due to Yellowtail Dam operations at Bighorn Reservoir, whereas the period of most strongly reduced flows (May to July) shows a much stronger influence of Yellowstone River irrigation on streamflow patterns. Based on the estimates, the primary influence on flow reductions in August and September is irrigation.

4.3.2.5 Consideration of Climate

On a state-wide basis, virtually all model simulations developed in support of the state water plan project predict earlier runoff and reduced summer flows (Montana DNRC, 2014). Median daily hydrographs compiled for pre- and post- 1990 data on the Yellowstone River at Livingston corroborate this general pattern; over the past 15 years, runoff has typically started about a week earlier and peaked 10 days earlier than it typically did between 1896 and 1990.

Previously published literature (Leppi et al. 2012) shows that reduced late August streamflow can be associated with climatic trends. Low flow analysis from a largely pristine gage at the Yellowstone Lake outlet indicates low August flows have been associated with increased air temperature.

Tree-ring analyses of the basin show that the twentieth century was a wet period relative to the several centuries prior, and that droughts have historically been substantially longer and more intense than those recently experienced in the basin.

Table 4-3 shows a summary of specific human influences described in this section, along with the associated impact, spatial extent of that impact, and relative magnitude of the impact. Although there are additional factors that will affect the system hydrology such as storm water management, these other influences are either considered to be relatively small or lacking in data.

4.3.3 Primary Human Influences on Yellowstone River Hydrology

The results of the hydrologic analyses indicate that the historical hydrology of the Yellowstone River was markedly different than it is today. The influences causing those changes include both consumptive and non-consumptive water uses, which collectively alter both the amount and timing of water delivery in the system. Although there are multiple types of both consumptive and non-consumptive water use, the main alterations to the hydrology of the Yellowstone River are due to irrigation and flood control. Climate trends have been identified as influencing low flow hydrology, and those influences are predicted to become stronger in the future. The following section contains a discussion of these influences, with selected results of the hydrologic analysis provided. For a more thorough presentation of the results, see Appendix 2 (Hydrology).

Table 4-3
Summary of Human Impacts to Yellowstone River Hydrology

Human Influence	Hydrologic Impact	Spatial Extent	Relative Impact to Hydrograph
Altered Hydrology on Bighorn River (Yellowtail Dam)	Reduced Peak Flows	Below Bighorn	Major
	Increased Winter/Fall Low Flows	Below Bighorn	Major
	Reduced Summer Low Flows	Below Bighorn	Major
	Reduced Rise/Fall Rates	Below Bighorn	Moderate
	Reduced Channel Forming Flows	Below Bighorn	Major
	Dampened March/April Prairie Peak	Below Bighorn	Moderate
Irrigation Consumptive Withdrawals	Reduced Flow	System-wide	Moderate
	Reduced Low Flow	System-wide	Moderate
	Reduced Channel Forming Flow	System-wide	Moderate
Municipal and Industrial Consumptive Withdrawals	Reduced Flow	Localized	Minor
	Reduced Low Flow	Uncertain	Uncertain
Non-Consumptive Withdrawals	Altered Flow Patterns	System-wide	Uncertain
Floodplain Isolation	Reduced Flood Storage	System-wide	Uncertain
Climate Trends	Uncertain	System-wide	Uncertain

While reviewing the data presented below, it is important to note that multiple drivers may be influencing any given dataset. For example, the influences of Bighorn River flow alterations are evident as a major shift in hydrologic statistics between the unregulated and regulated flow conditions at the mouth of the Bighorn River. That impact overlies a broader trend of Yellowstone flow alterations due to irrigation.

4.3.3.1 Influence of Bighorn River Flow Alterations on Yellowstone River Hydrology

As described previously, Yellowtail Dam is operated in support of irrigation, flood control, and power generation. These uses, as well as evaporative losses and other flow alterations upstream of Bighorn Reservoir, result in a change in the patterns and magnitudes of water delivered downstream to the Yellowstone River. The changes described below include reductions in high flows, channel-forming flows, summer low flows, and increases in winter flows.

Reduced High Flows

Figure 4-34 shows the results of the unregulated/regulated flow comparison for the 100-, 10- and 2-year floods on the Yellowstone River. The values are plotted as the percent change estimated for each reach of the river, starting at Gardiner and continuing downstream to the mouth of the river below Sidney. The plot shows that from Gardiner to the Clarks Fork River, the drop in peak flows is less than 5 percent. These reductions are primarily due to flow depletions associated with irrigation. The continued influence of irrigation is shown from the mouth of the Clarks Fork to the mouth of the Bighorn, where the change is generally 10 percent or less, with the 2-year flood (50% probability) showing the greatest percent change.

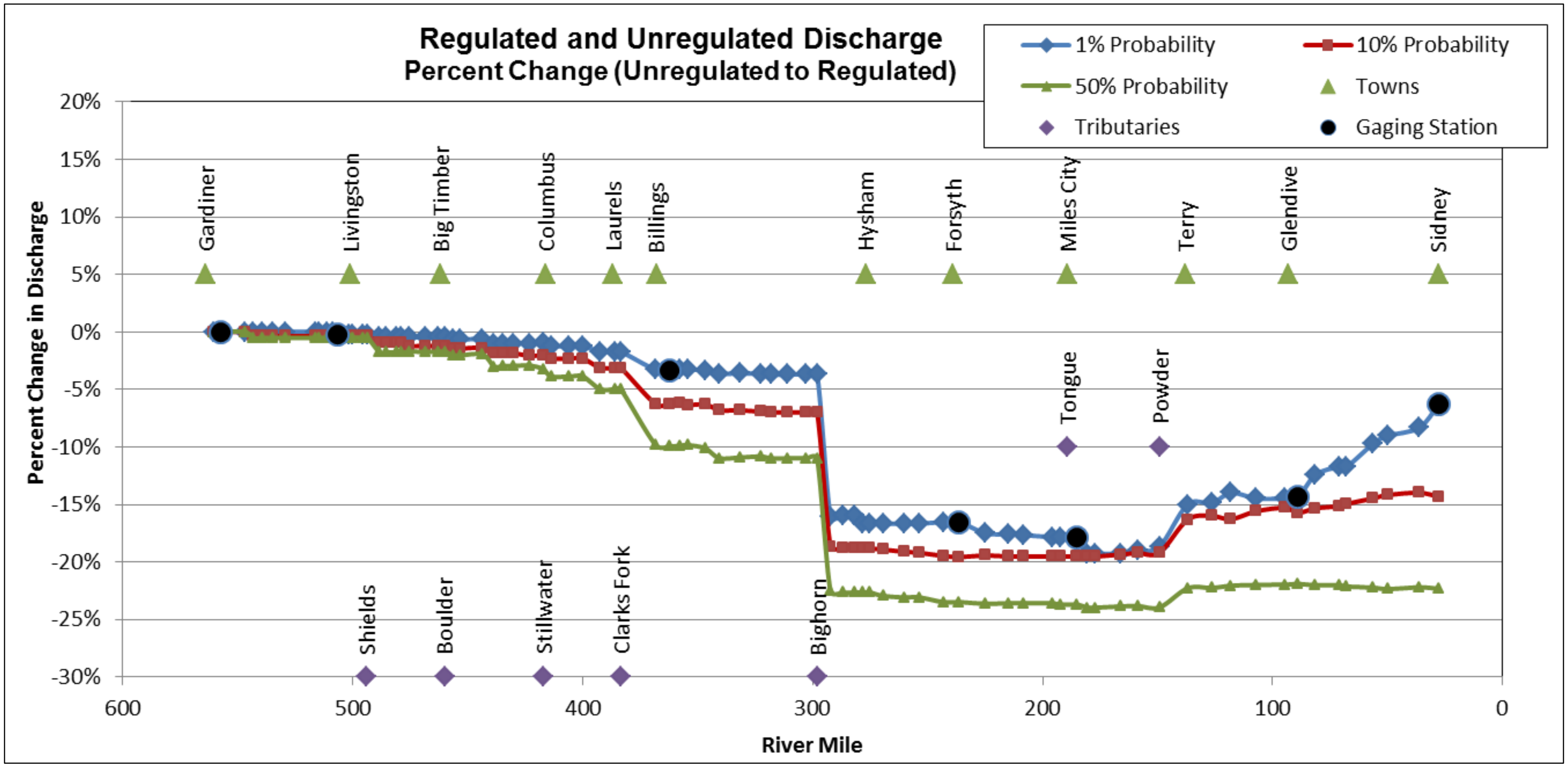


Figure 4-34 **Percent change in 1%, 10%, and 50% annual exceedance probability discharge, regulated and unregulated conditions**

The influence of Bighorn River flow alterations becomes evident at the mouth of the Bighorn River, where there is a major deflection in each line. These deflections show an increase in the impact of human development on flows, and the trend is towards a reduction in peak flow. When viewed in terms of absolute discharge, the reduction in the 100-year flood discharge below the mouth of the Bighorn River is about 20,000 cfs (Figure 4-35).

Figure 4-34 shows that flow alterations on the Tongue River due to Tongue River Reservoir show little relative impact on Yellowstone River flows. Downstream of the mouth of the Powder River, the influence of Yellowtail Dam operations on Yellowstone River flood flows is diminished, although still evident.

Reduced Channel Forming Flows

Channel forming flows, which are the flows largely responsible for defining basic river morphology such as size, shape, and pattern, were evaluated in terms of both the 2-year flood event (50% probability) and the 5-percent duration flow. Both of these statistics reflect the typically snowmelt-related runoff and have been used to approximate channel forming discharges. Similar to the 100-year event, the magnitudes of these events have dropped markedly at the mouth of the Bighorn River relative to upstream. The 2-year flood magnitude below the mouth of the Bighorn River has dropped by approximately 14,000 cfs or 23 percent under developed conditions (Figure 4-36). However, it is critical to note that even though there is an abrupt shift at the mouth of the Bighorn, about half of that total change had already occurred upstream at the Billings gage (Reach B2). Thus the 2-year flood has been significantly impacted by both Bighorn River hydrology and consumptive water use or other impacts along the Yellowstone and its other tributaries.

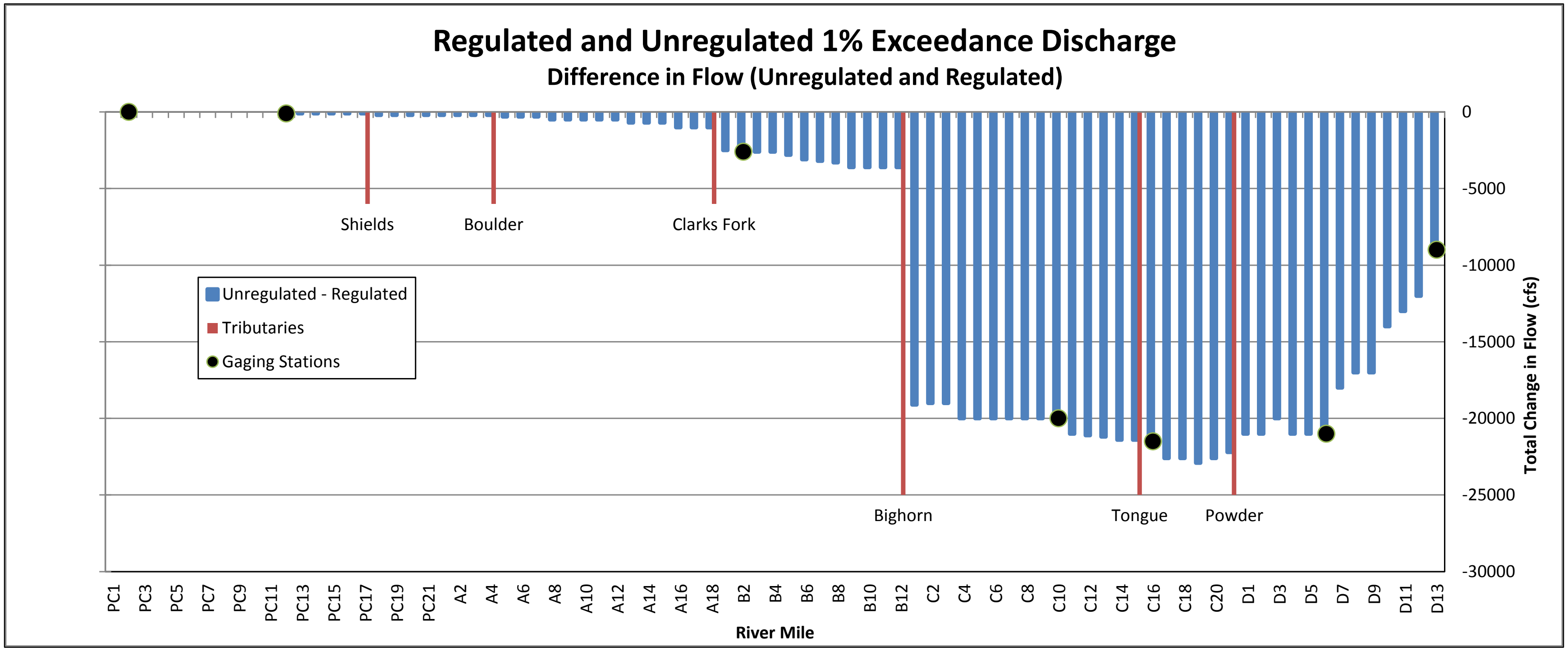


Figure 4-35 Change in flow rates (unregulated from regulated) for the 1% exceedance flow (100-year flood) plotted by reach
Note: *Reach values interpolated by drainage area.*

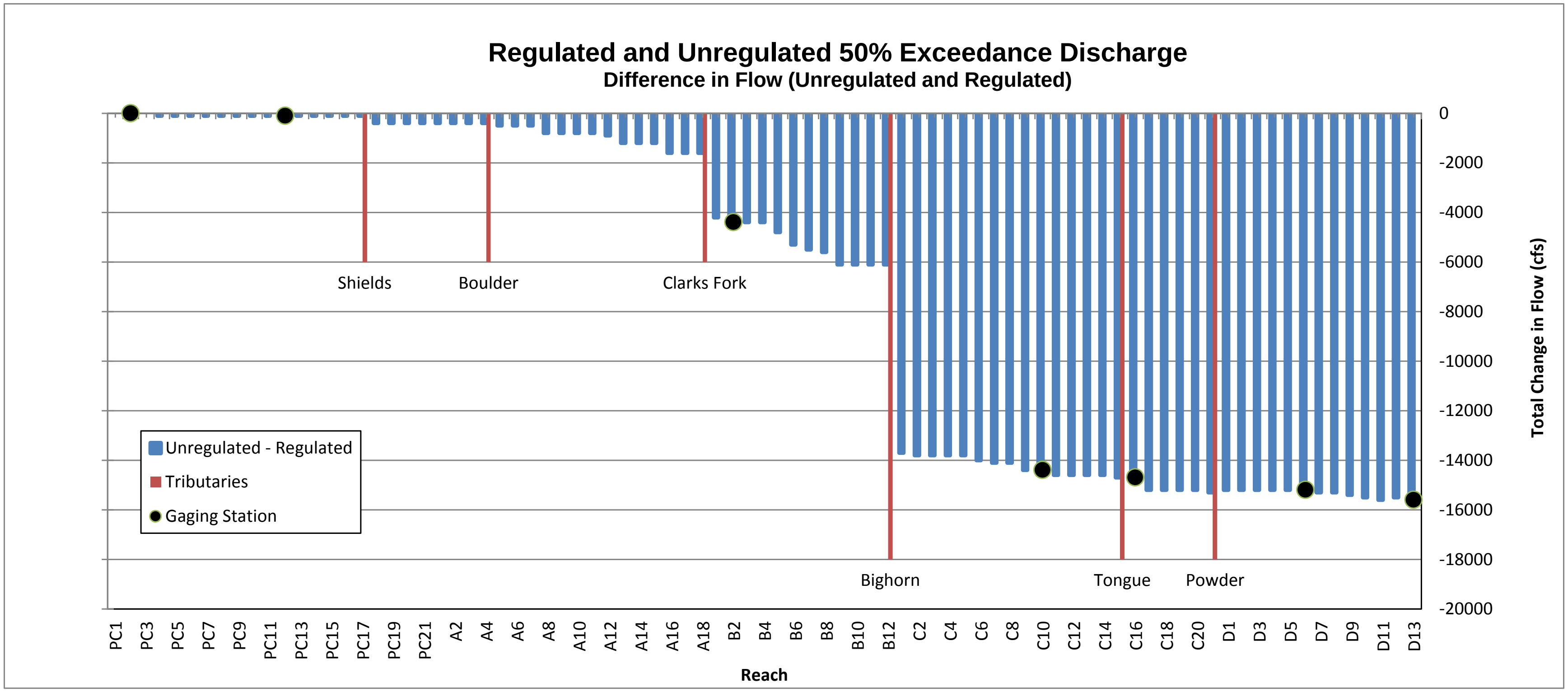


Figure 4-36 Change in flow rates (unregulated from regulated) for the 50% exceedance flow (2-year flood) plotted by reach

Changes in Mean Monthly Flows

When flows are considered on a monthly timeframe, there are distinct patterns that show flow reductions in summer and increases in the winter both above and below the mouth of the Bighorn River. Figure 4-37 shows that gages located upstream (Billings) and downstream (Forsyth) of the mouth of the Bighorn River both show the same trend; however, the changes are amplified at Forsyth. This is indicative of the combined influences of dam operations and irrigation patterns. Summer flows are reduced due to both storage at Yellowtail Dam and irrigation, and winter flows are increased due to Yellowtail Dam release patterns, as well as some apparent irrigation water return flow, as seen at the Billings gage (Figure 4-37).

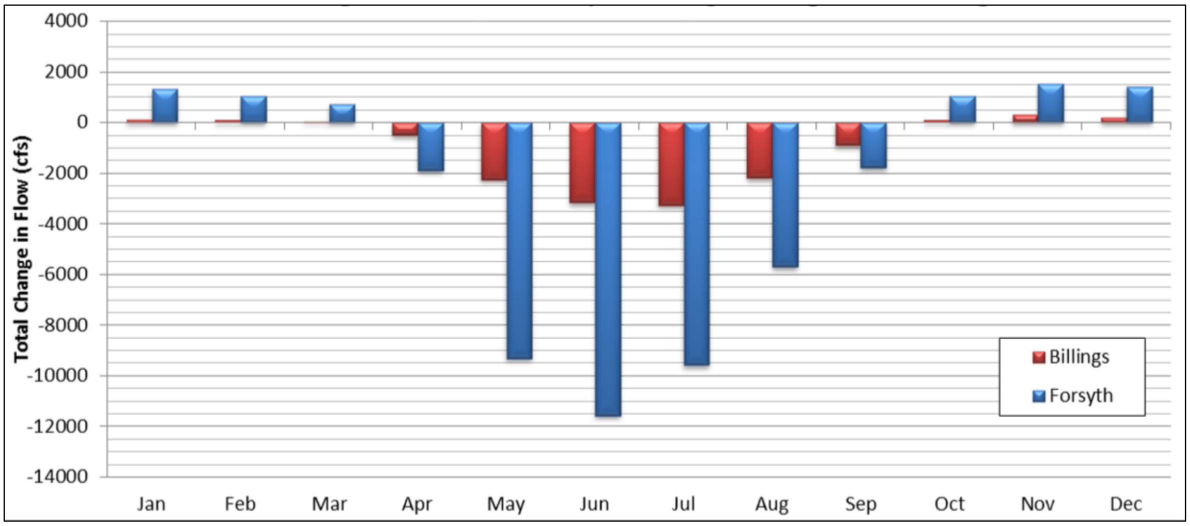


Figure 4-37 Total change in mean monthly discharge from Unregulated to Regulated Conditions, Billings and Forsyth

Reduced Summer Low Flows

Summer low flows were evaluated by looking at the flows that are equaled or exceeded 95 percent of the time (95% flow duration) from July through September. The most significant impact has been to summer flows when unregulated discharges have been reduced by almost 60 percent below the mouth of the Powder River (Figure 4-38). Similar to the other datasets, there are also reductions at Billings; however, those reductions are several thousand cfs less than below the mouth of the Bighorn River.

Summer low flow patterns show an overall river-wide reduction in the lowest summer flows, which have been evaluated by the 7Q10 statistic. The 7Q10 is the lowest 7-day average flow expected to occur every 10 years. The summer 7Q10 has dropped by about 1,000 cfs at Billings and 1,500 cfs below the mouth of the Bighorn River (Figure 4-39). In 1986, the U.S. Environmental Protection Agency (EPA) recommended the use of this statistic for water quality standards and toxic waste load allocation studies related to chronic effects on aquatic life (U.S. EPA 1986).

Increased Winter/Fall Flows

Flow duration analysis shows a clear increase in fall and winter flows at the mouth of the Bighorn River (Figure 4-40). This is a typical consequence of dam operations where naturally low flows are boosted by dam releases during the fall and winter seasons. At Miles City, winter low flows (95% duration) have increased by about 1,000 cfs under developed conditions. Figure 4-41 shows a summary of the seasonal shifts in low flows by location, showing consistent reductions in spring and summer flows and increases in fall and winter flows at all locations.

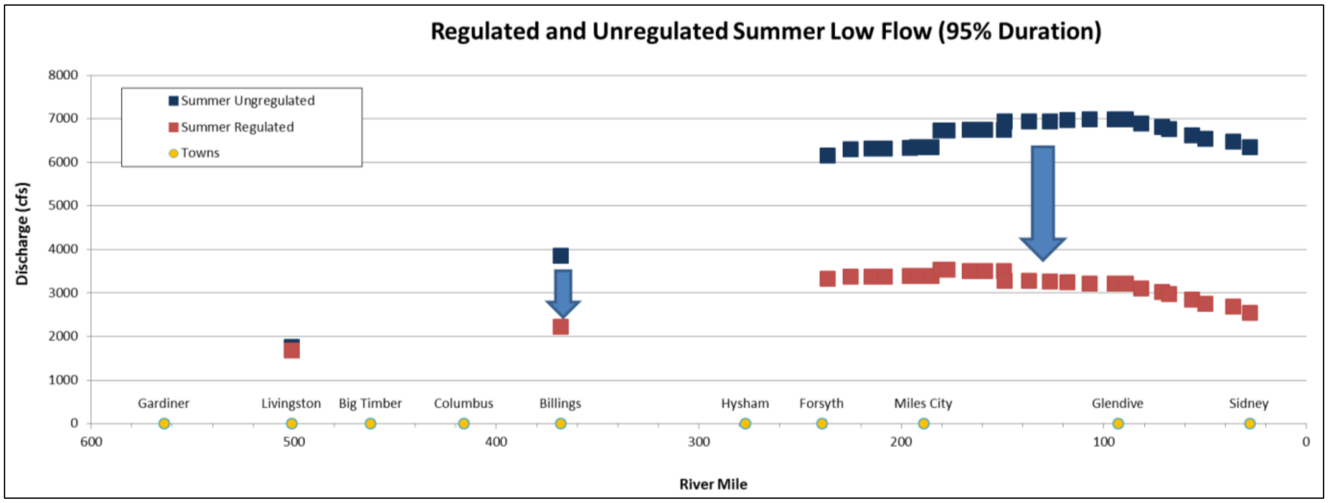


Figure 4-38 Regulated and unregulated summer (July-September) low flow discharges

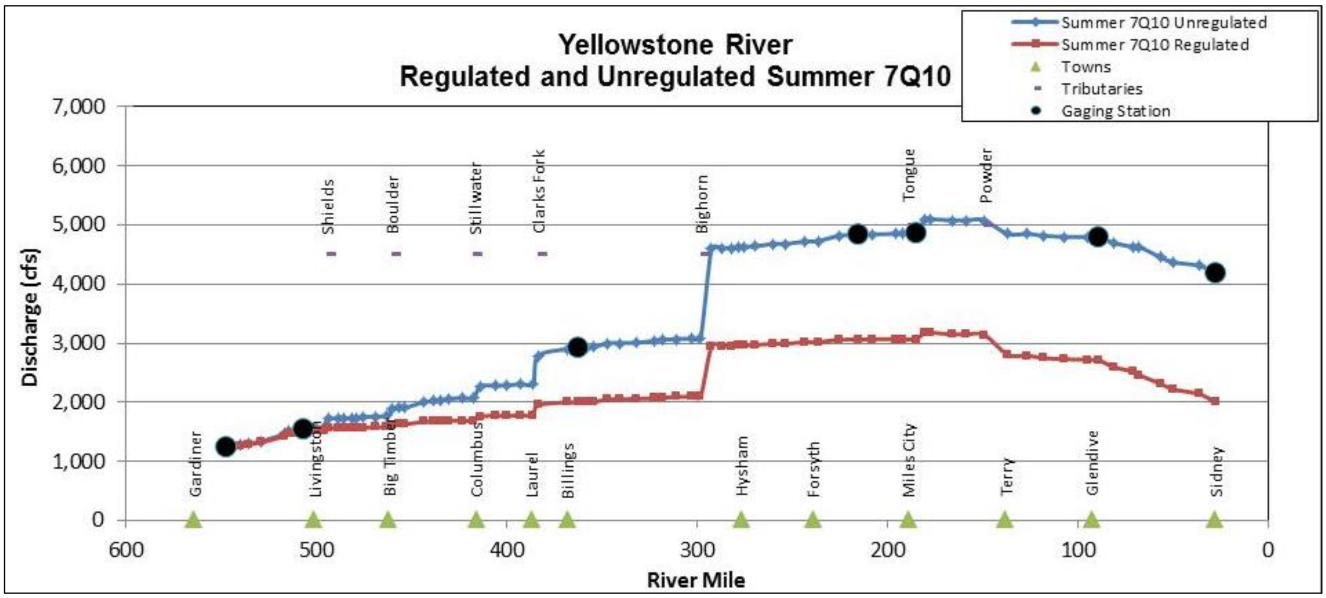


Figure 4-39 Summer 7Q10 for regulated and unregulated conditions

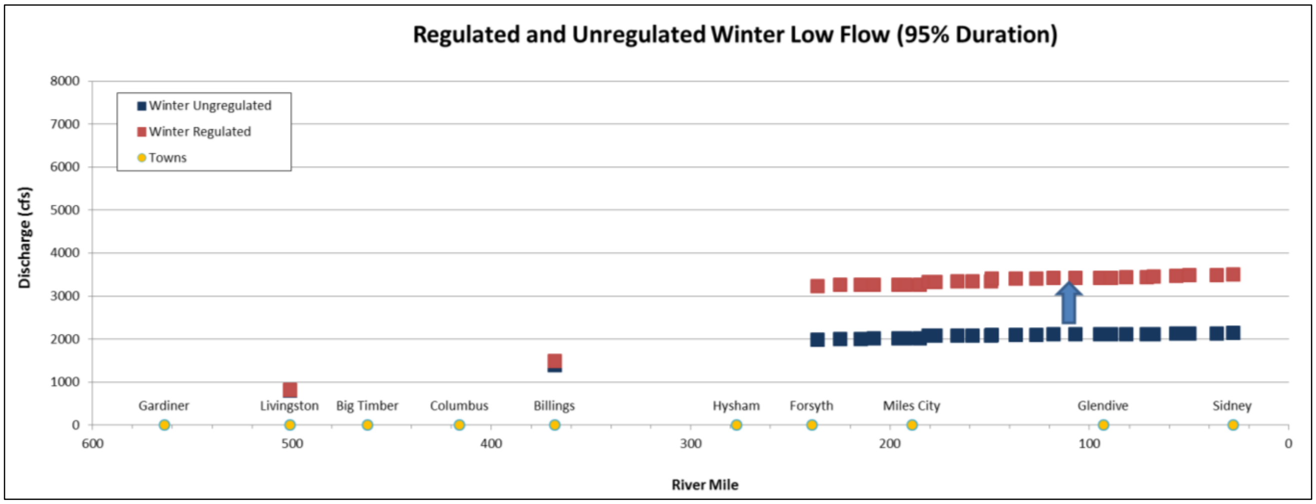


Figure 4-40 **Regulated and unregulated winter (January-March) low flow discharges**

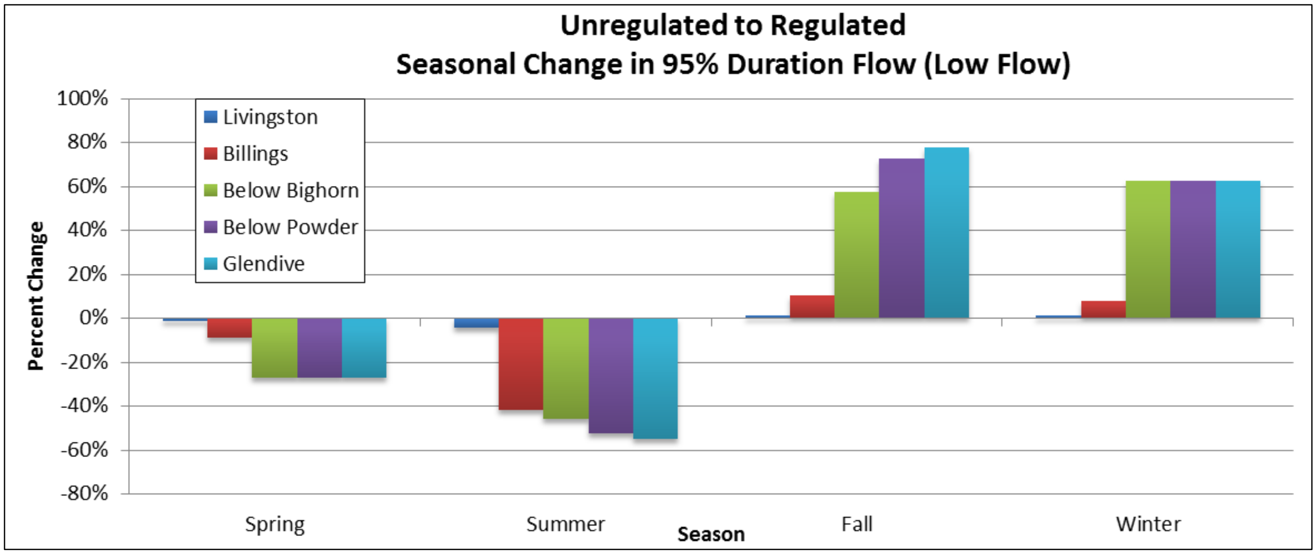


Figure 4-41 **Seasonal shifts in 95% duration discharge for selected Yellowstone River locations**

Yellowtail Dam Operations

The conclusion that Yellowtail Dam operations have served to reduce peak flows, reduce summer flows, and increase winter flows on the Yellowstone River is supported by dam operations data. Figure 4-42 shows average annual inflow and outflow hydrographs Bighorn Reservoir. The inflow pattern (blue) shows average peak flows of 8,000 cfs, fairly low winter flows of about 2,000 cfs, and a distinct early snowmelt runoff peak in March. The release pattern is much different, with a lower peak (~5,000 cfs), increased winter flows, and an overall "dampening" of the hydrograph, which also removes the early March runoff pulse. A median daily flow hydrograph showing pre- and post- Yellowtail Dam flows at the Sidney gage shows the same pattern (Figure 4-43).

4.3.3.2 Influence of Irrigation on Yellowstone River Hydrology

The unregulated/regulated flow comparisons show changes both upstream and downstream of the Bighorn River confluence, indicating that influences other than those associated with Bighorn River flow alterations and Yellowtail Dam operations have affected Yellowstone River flows. Results of this analysis indicate that the other primary impact is irrigation. Over 90 percent of the water used in the counties of the Yellowstone River Basin in 2000 was for irrigation (Figure 4-44 and Figure 4-45).

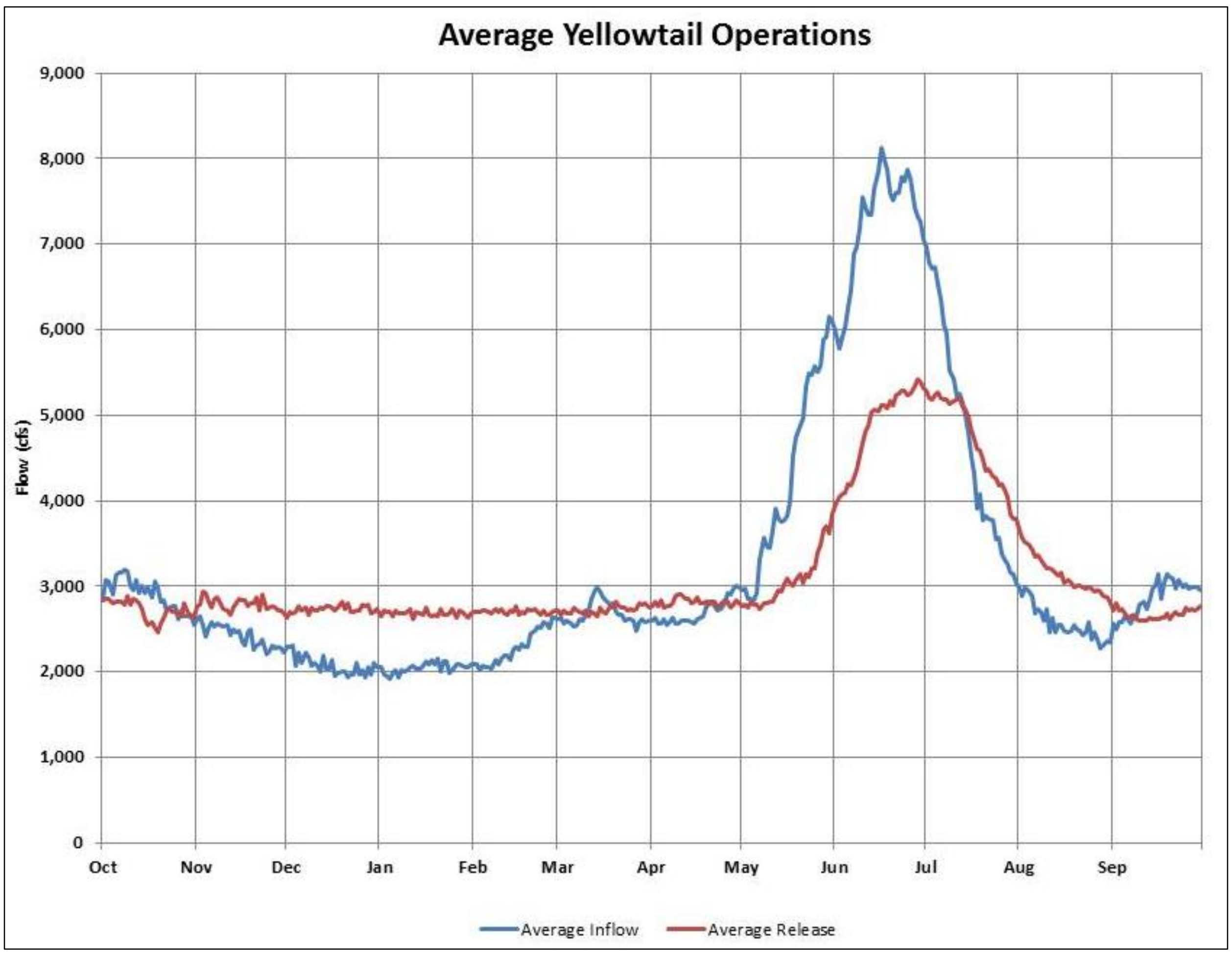


Figure 4-42 Average Bighorn Reservoir inflow and outflow hydrographs
Note: Typical inflow at the head of the reservoir (blue) and typical release patterns (red).

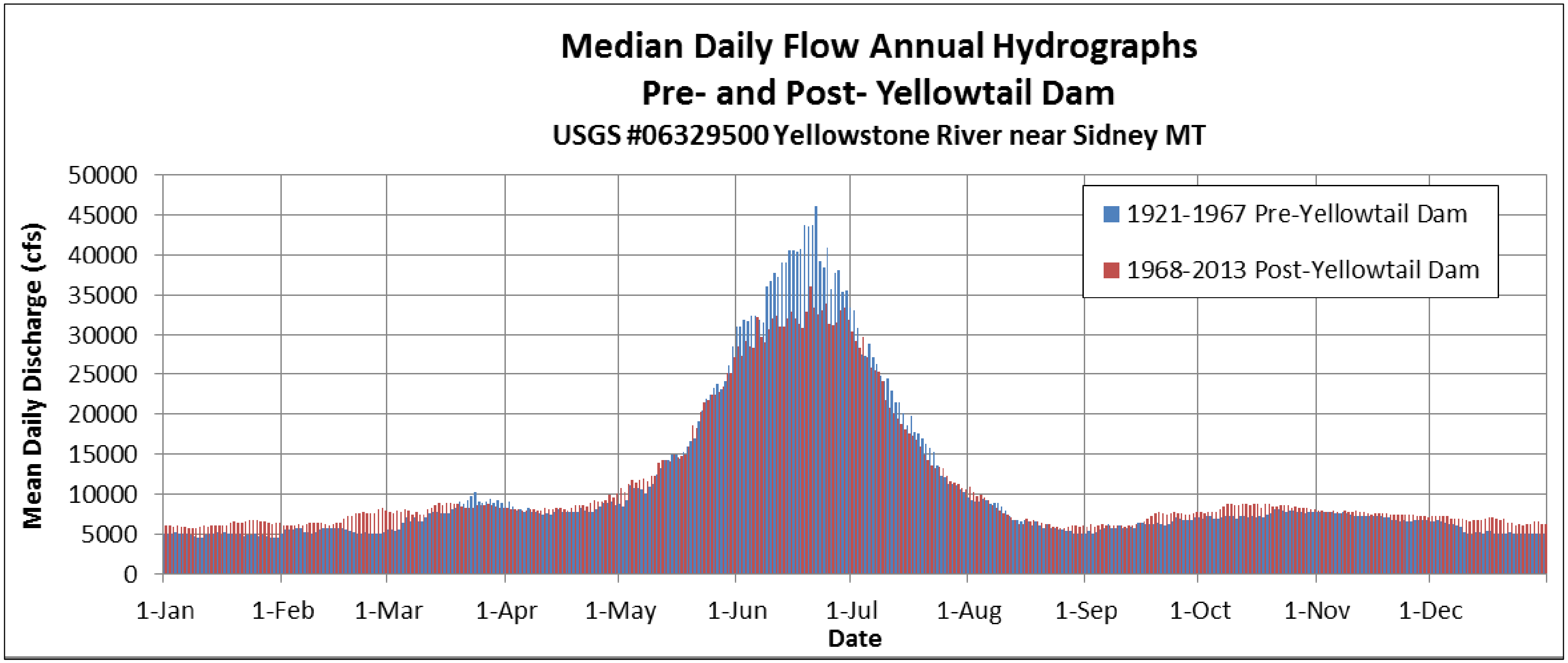


Figure 4-43 Median daily flow annual hydrographs for pre- and post- Yellowtail Dam conditions, Yellowstone River near Sidney MT

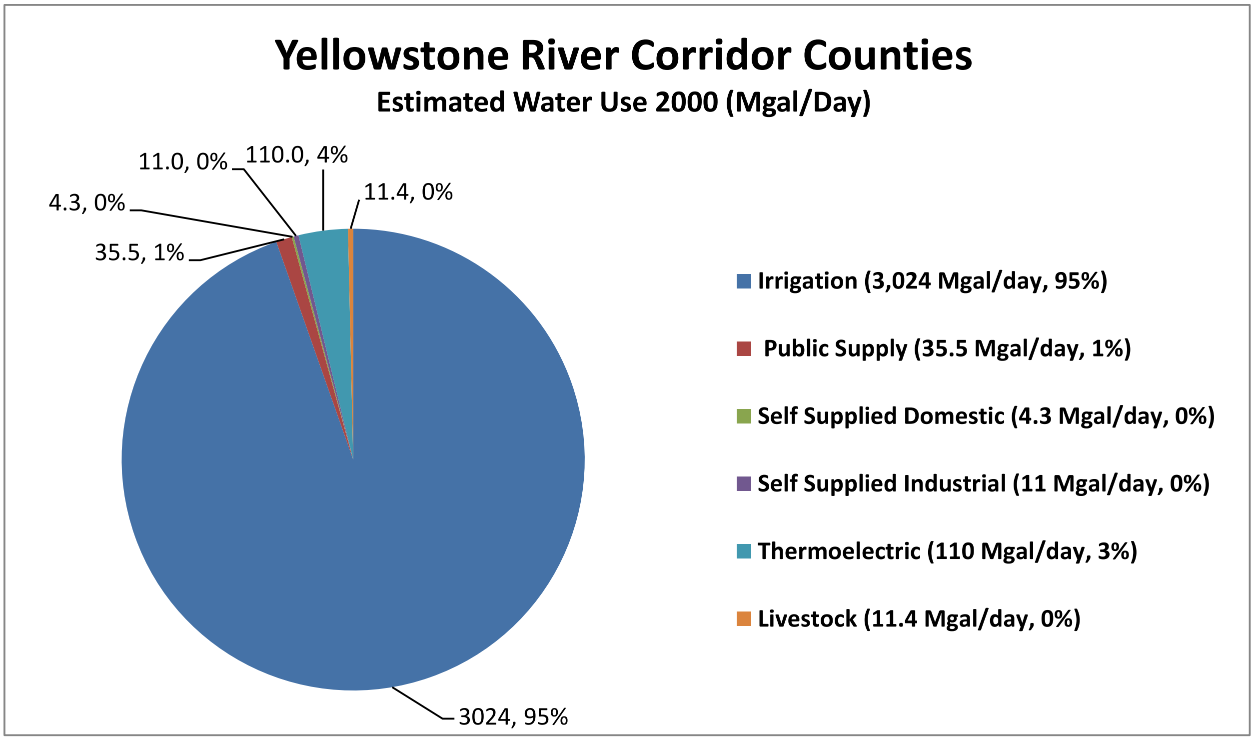


Figure 4-44 Yellowstone River Counties, estimated year 2000 water use by type of use (Mgal/Day)

Source: www.fws.gov

Figure 4-45 Huntley Irrigation Project below Billings

The total estimated amount of water withdrawn for irrigation on the Yellowstone River Basin in 2000 was 3,024 million gallons per day. Without considering flow returns, this translates to a total estimated surface water irrigation rate of 4,660 cfs averaged over the entire year. If the irrigation season is considered to be four months long, the potential rate of surface water withdrawals is almost 14,000 cfs, during the four month season. This water is not all consumed however; the total consumptive use for irrigation is estimated to be about 20 percent of the total withdrawal value (Cannon and Johnson 2004). Much of the non-consumed water returns to the river later in the season (see Appendix 2 (Hydrology)). The total estimated consumptive water use for irrigation in the Montana portion of the Yellowstone River corridor is 588 million gallons per day, or about 660,000 acre-feet per year.

Figure 4-46 shows the estimated irrigation withdrawals for irrigation by basin. For these data, the "Upper Yellowstone" refers to the river corridor basins above Billings; the "Middle Yellowstone" refers to the valley from Billings to the Bighorn River confluence, and the "Lower Yellowstone" refers to the stream valley below the Bighorn River and includes the Big Porcupine drainage north of Forsyth and O'Fallon Creek. All other major contributing drainages are summarized independently. The "Bighorn" drainage includes only the Lower Bighorn River drainage area below Yellowtail Dam and the Little Bighorn River drainage; none of the summary values include any water use in Wyoming.

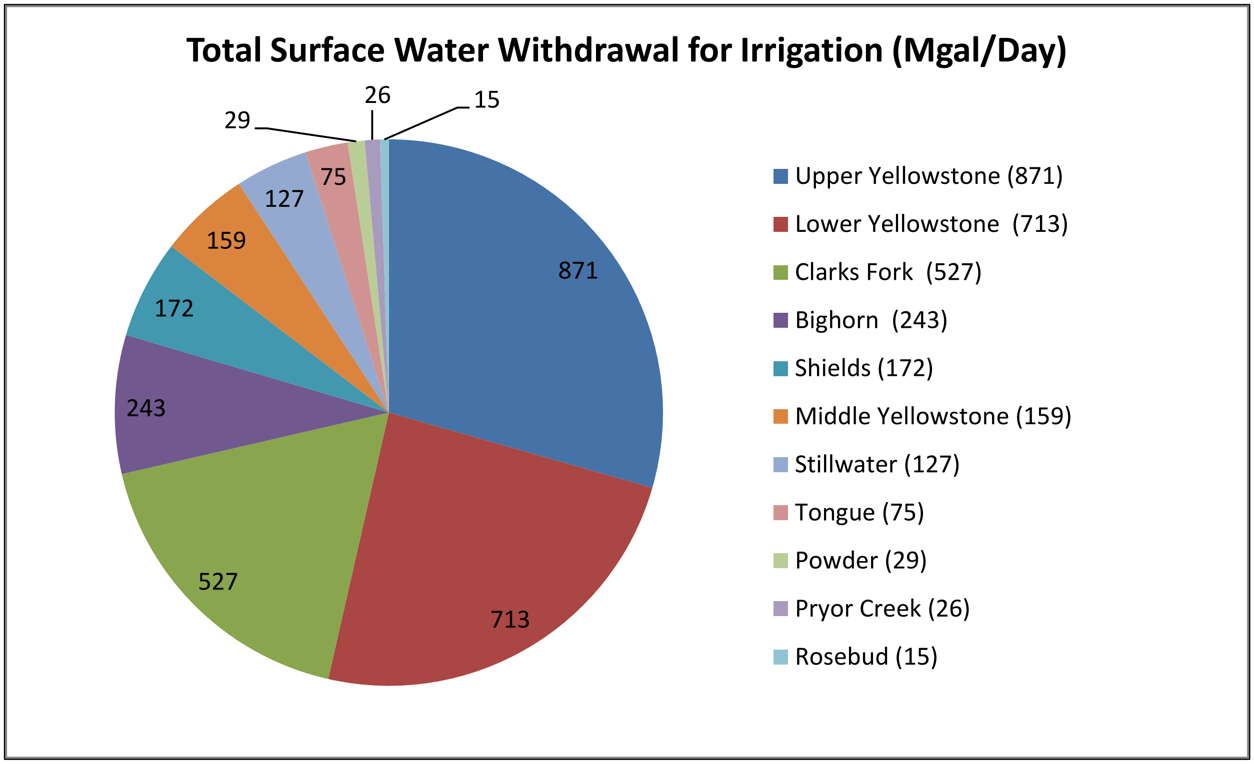


Figure 4-46 Estimated 2000 water withdrawals for irrigation by drainage basin

The summaries show that the Upper Yellowstone, Lower Yellowstone, and Clarks Fork drainages collectively account for almost 75 percent of the total irrigation water withdrawals in the Montana portion of the Yellowstone River watershed in 2000. The large proportionate diversion of water in the Clarks Fork basin is consistent with an abrupt increase in flow alterations at the mouth of the Clarks Fork (e.g., Figure 4-36).

The influence of irrigation on Yellowstone River hydrology relates to both consumptive use, which reduces total volume of water in the river, as well as non-consumptive use, which changes the patterns of flows in the river. These patterns are depicted in the trends seen at Billings, where reductions in summer flows have been accompanied by an increase in flows in fall and winter.

Reduced 2-Year Flood Flows

Figure 4-36 shows that above the Bighorn confluence, the 2-year flood flow has been reduced due to development throughout the river system, with the impact increasing in the downstream direction. There is a distinct increase in the impact at the mouth of the Clarks Fork River; downstream of this point, the 2-year flood has been reduced by over 4,000 cfs.

Reduced Low Flows

Low flow statistics show a substantial decrease in the summer 7Q10 under regulated (developed) conditions on the entire river. The 7Q10 is the lowest 7-day average flow expected to occur every 10-years. The 7Q10 shows the following reductions from undeveloped (unregulated) to developed (regulated) conditions: Livingston: 3 percent, Billings: 31 percent, Miles City: 37 percent, and Sidney: 52 percent. At the Billings gage, the summer 7Q10 has dropped by approximately 1,000 cfs, and at Sidney it has dropped by 2,190 cfs. The influences of consumptive withdrawals through irrigation dominate the impacts upstream of the Bighorn River confluence, and those impacts are substantial.

Reduced Mean Monthly Flows

Upstream of the Bighorn River confluence the primary consumptive water use affecting the Yellowstone River is irrigation. Mean monthly flow data show that at Billings, the mean monthly discharge in August has dropped from about 7,500 cfs to 5,300 cfs, a shift that can be largely attributed to irrigation. Irrigation also appears to have slightly increased flows in the river during the late fall. Mean monthly flows in November, for example, have increased from 3,200 cfs to 3,500 cfs. This is evidently the result of late season irrigation return flows. The influence of irrigation on mean monthly flows continues below the Bighorn River confluence. Although Bighorn River flow alterations have had a major impact on flow patterns, the primary influence on reductions in mean monthly flows during August and September at the Forsyth gage appears to be non-Bighorn related irrigation (Figure 4-47). The influence of irrigation on river flows at Forsyth increases through the spring months and peaks out in September, when almost 70 percent of the changes in flow are due to non-Bighorn River related water use.

4.3.4 Other Potential Influences on Yellowstone River Hydrology

The primary human influences on Yellowstone River hydrology have been determined to be altered hydrology on the Bighorn River, as well as irrigation within the remainder of the Yellowstone River Basin. Although the available data indicate that these are by far the dominant drivers of hydrologic alteration on the Yellowstone River; that does not presume that other influences have contributed to those impacts. Several of these potential influences are described below.

4.3.4.1 Tributary Water Storage

Stock ponds and other small storage reservoirs are very common in the Yellowstone River watershed and have the collective potential to significantly alter downstream hydrology under certain conditions (Figure 4-48). While this impact is acknowledged in the Yellowstone River Basin, the impact has not been evaluated to any level of detail.

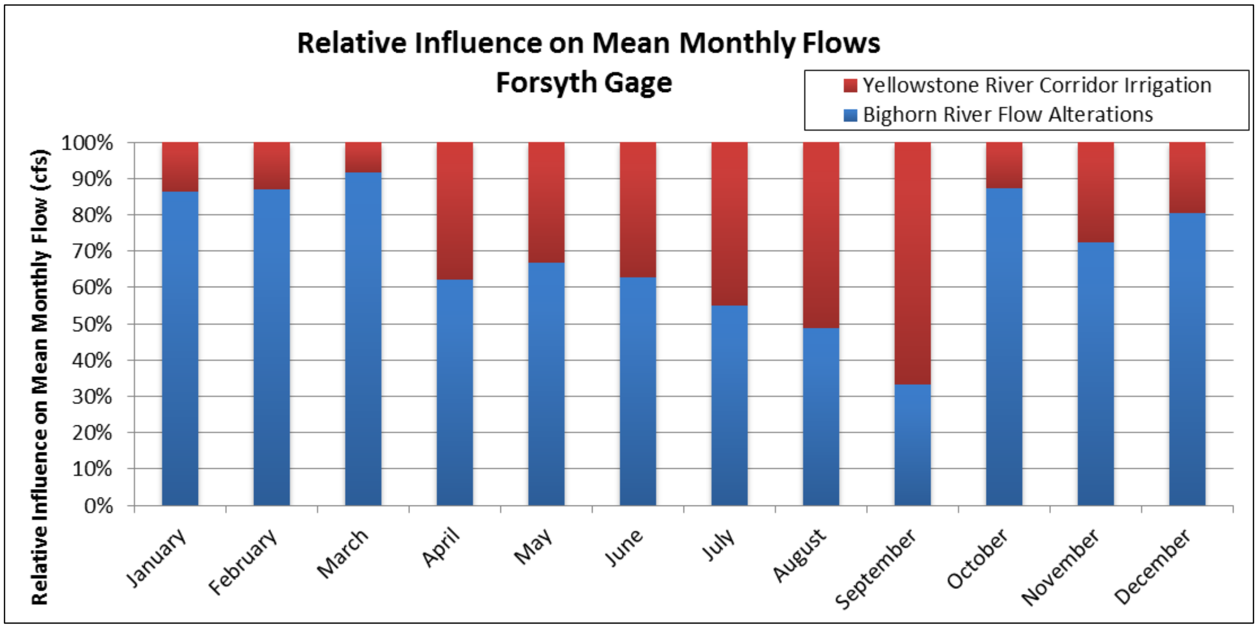


Figure 4-47 Estimated relative influence of Yellowtail Dam operations and irrigation on monthly flows at Forsyth

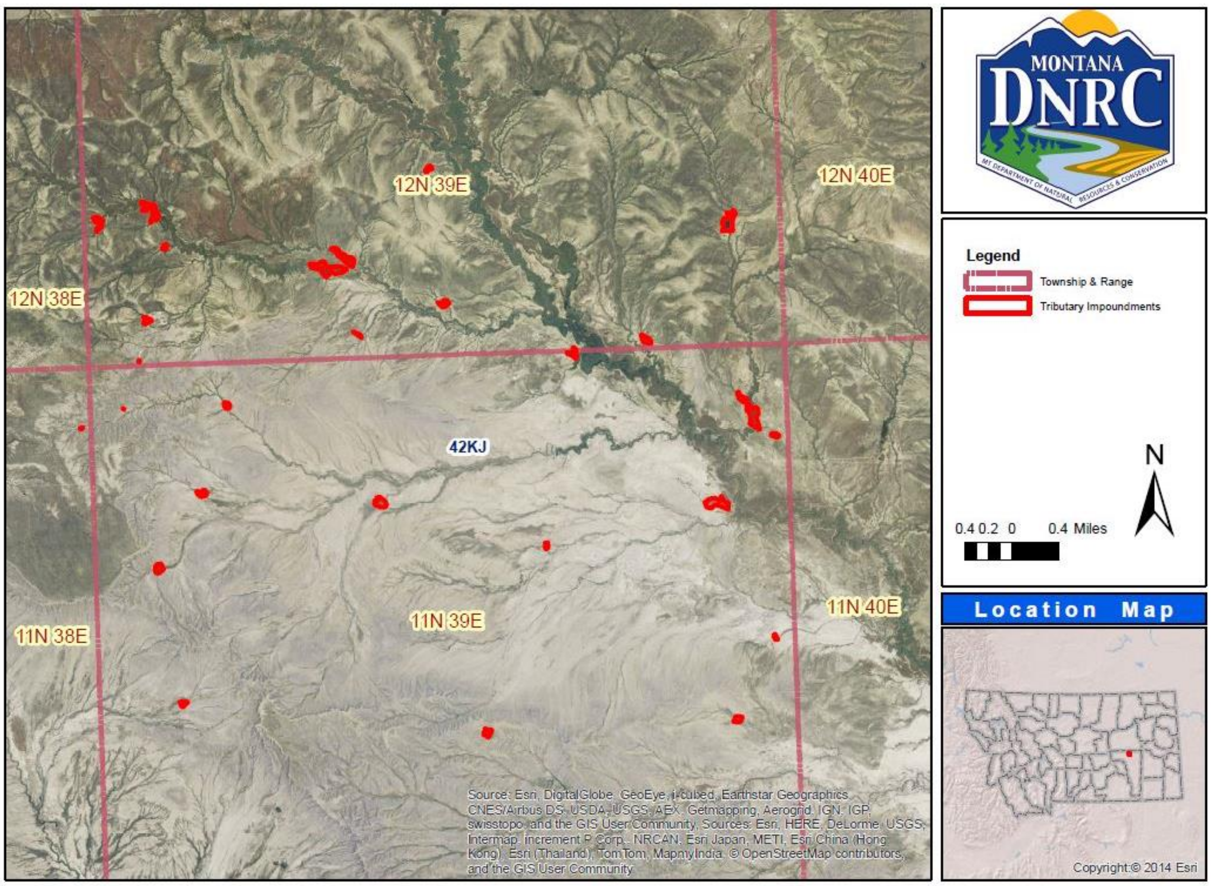


Figure 4-48 Tributary impoundments on a portion of the Porcupine Creek drainage, a lower Yellowstone River tributary

As the results of the hydrologic analysis indicate that the 100- and 10-year flood magnitudes have been reduced at major tributary confluences such as the Clarks Fork, it is likely that these tributary storage reservoirs contribute to some extent to the mitigation of flood peaks. This effect would be most pronounced when the reservoirs have the capacity to store sufficient water to affect the flow peak. Under most antecedent conditions, however, their largest impact is likely on low flows when the reservoirs can store the vast majority of runoff. Particularly in the eastern part of the Yellowstone River Basin, downstream of Billings, ephemeral streams flow only during low elevation snowmelt and precipitation events. These streams are commonly dammed for stock water or diverted by dikes in water spreading systems. Except during high runoff events, effectively all the flow in these streams is diverted or impounded. The impact of water spreading and small impoundments will be to reduce flow to larger tributaries and eventually the Yellowstone River. These impoundments also limit connectivity of the drainage system. Because these streams are strongly dependent on precipitation and may have their highest flow during any month of the year, the impact on Yellowstone hydrology would be temporally and spatially variable and difficult to distinguish from other effects. In so far as small impoundments recharge local ground water, the effect would be to spread the effect of precipitation events over a longer time period and moderate storm runoff. These and other consequences of tributary storage, such as low flow alterations and evaporative losses, have not been quantified herein.

4.3.4.2 Floodplain Isolation

Floodplain isolation is a common result of development through the construction of dikes, levees, and transportation embankments in the river floodplain. Although these features can protect areas prone to flooding, they also have the following potential impacts to river hydrology:

- Delivery of more water downstream at the flood peak
- Delivery of less water on the falling limb of a flood hydrograph
- Reduction of overbank infiltration and post-flood base flows.

Floodplain isolation is common throughout the Yellowstone River corridor. It has been related to transportation infrastructure, agricultural land uses, and urban/exurban development. Over 21,000 acres of 100-year floodplain area have been isolated between Springdale and the mouth of the river (Section 4.4.3). Although there is general consensus on the role of floodplains in storing floodwaters, quantification of the impacts of floodplain isolation on hydrologic statistics has not been performed for the Cumulative Effects Analysis (CEA). In general, however, a comparison of undeveloped and developed conditions indicates that flood magnitudes have dropped on the Yellowstone; such that any increase in flood discharge due to loss of floodplain storage is small relative to opposing impacts of water withdrawal and Yellowtail Dam. The extent and primary drivers of floodplain isolation in the Yellowstone River corridor are described in Section 4.4.3.

4.3.4.3 Municipal and Industrial water withdrawals

Although irrigation is the dominant water use in the basin, Yellowstone River counties use the most water in the state for cooling as part of thermoelectric power generation. Cannon and Johnson (2004) described how water used for cooling purposes at fossil fuel plants in Richland, Rosebud, and Yellowstone Counties amounted to the largest amount of surface water withdrawal after irrigation. Within Yellowstone and Richland Counties, almost all of the water used for cooling is returned back to the river. In Rosebud County, however, the water was not returned to the river following its industrial use. The total water consumed as part of thermoelectric power generation in 2000 was about 27.7 million gallons per day, most of which was consumed in Rosebud County. This is potentially significant especially during low flows, but it is about 8 percent of the estimated 331 million gallons per day consumed by irrigation.

Municipal water use constitutes only about 1 percent of the total water use in the counties occupying the Yellowstone River corridor. Figure 4-49 shows the non-irrigation water uses in those counties. The county with the most extensive municipal water withdrawals is Yellowstone County, which in 2000 consumed 65 percent of the total municipal amount (see Figure 4-50).

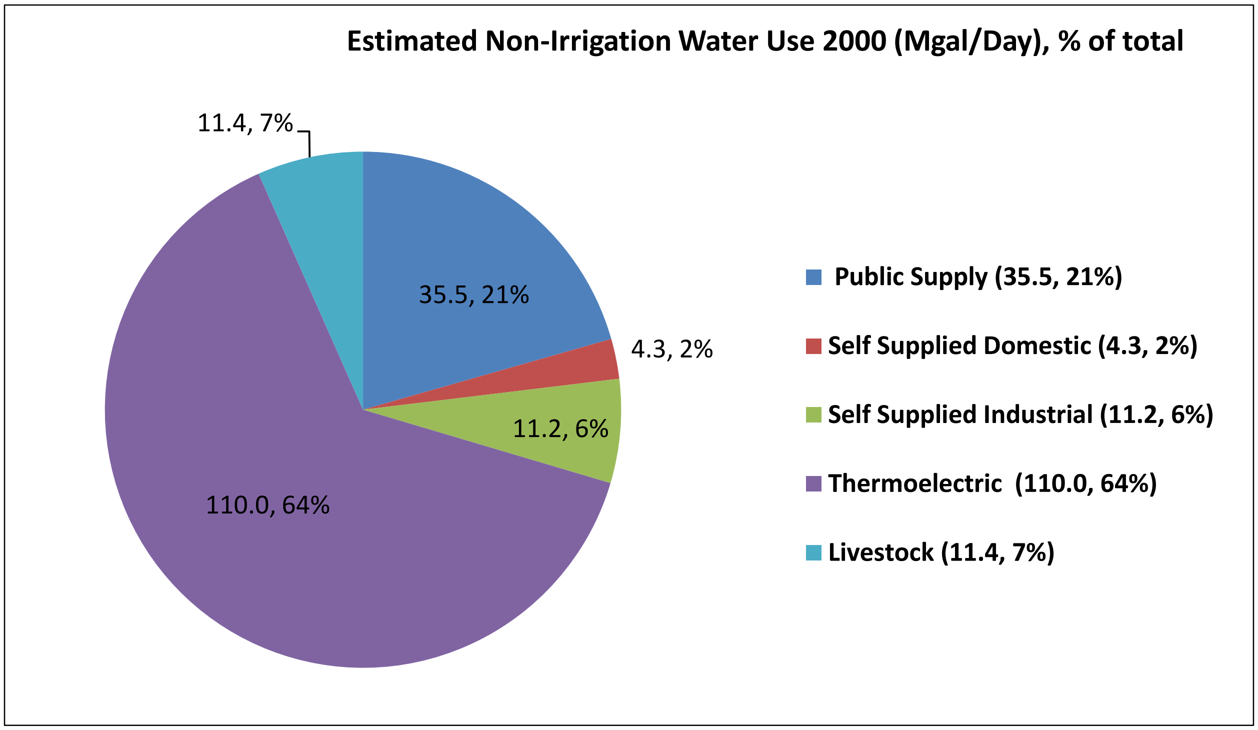


Figure 4-49 Non-irrigation water use estimated for year 2000, Yellowstone River corridor counties

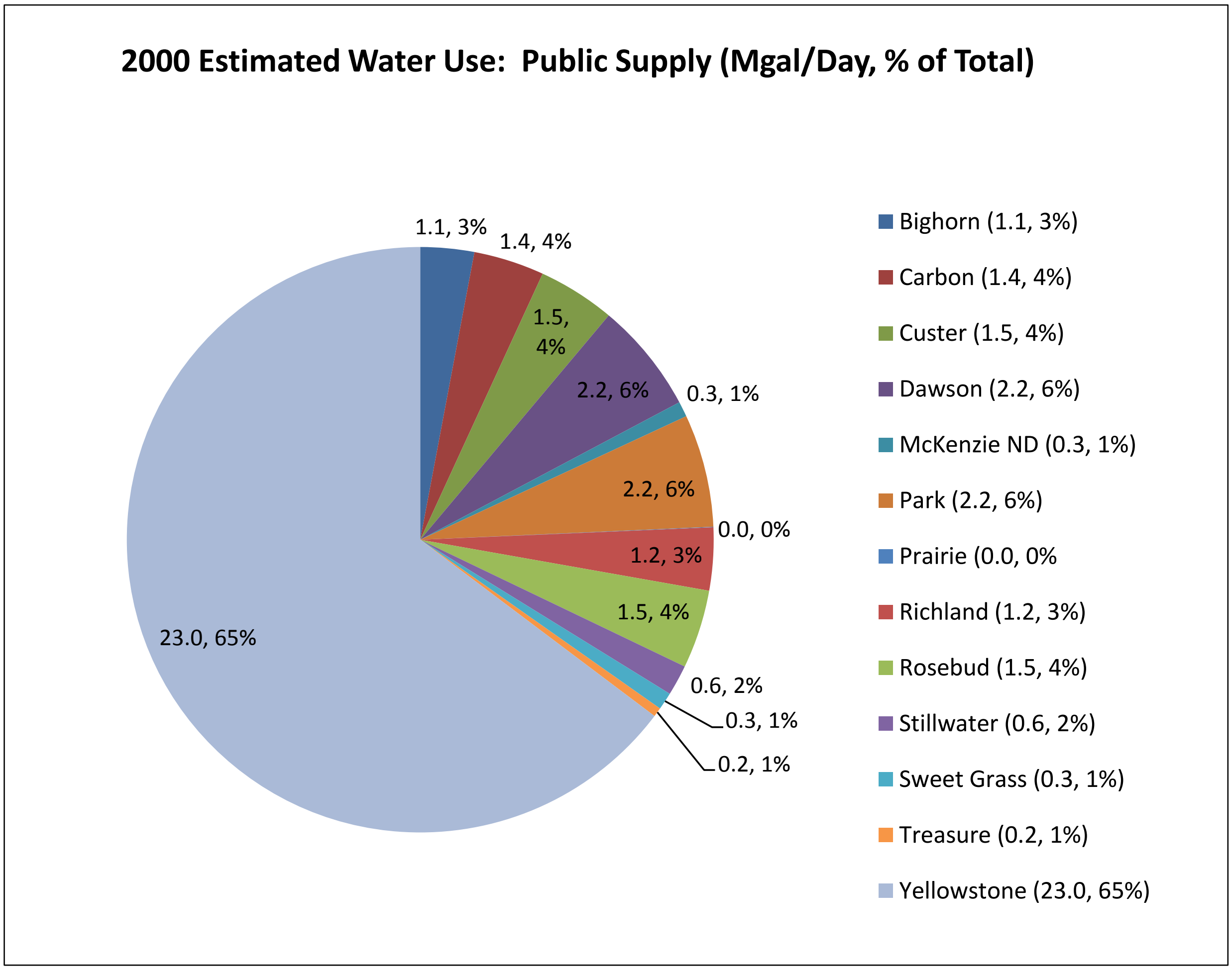


Figure 4-50 Municipal water use for year 2000 by county

4.3.4.4 Urban/Exurban Development

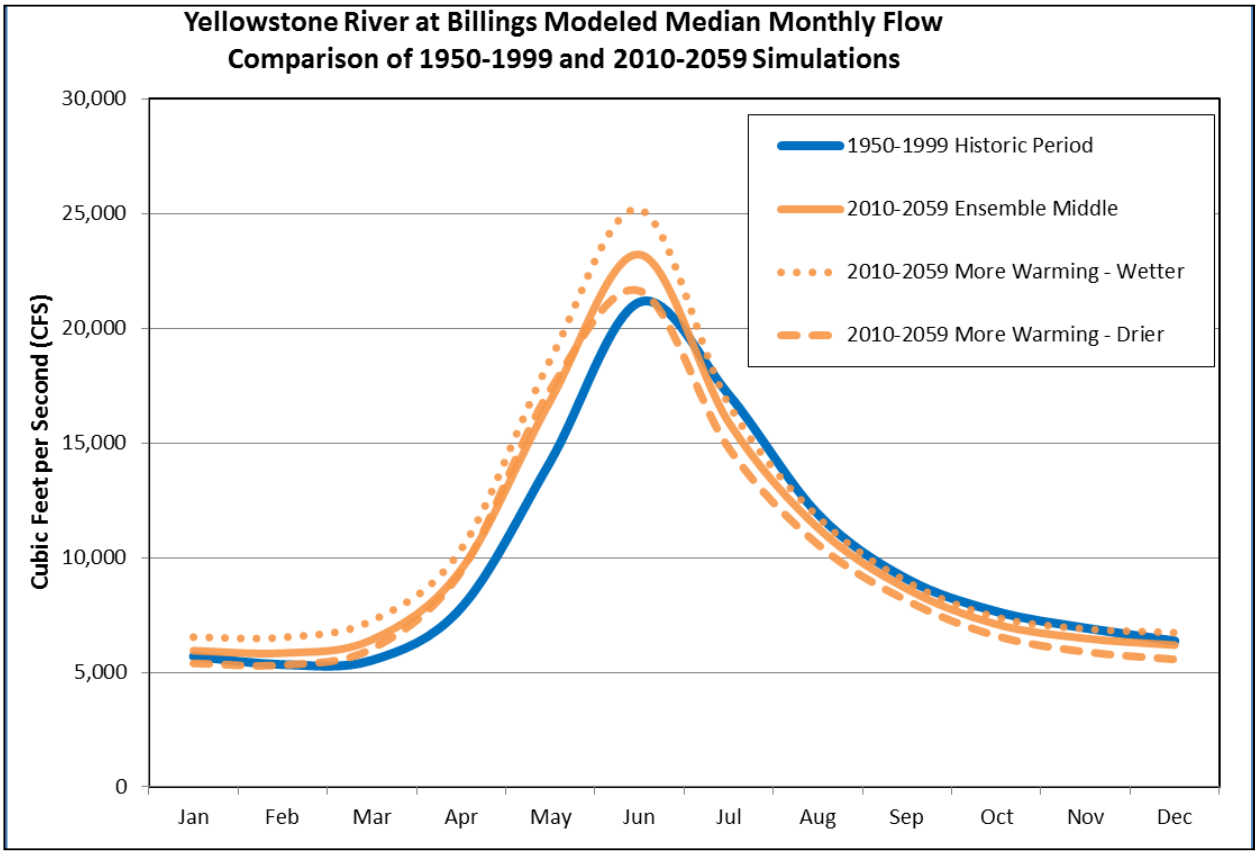
Floodplain development increases the extent of impervious surfaces such as paved roadways or housing footprints. The expansion of impervious surfaces, as well as drainage features such as curbs and gutters, affects the hydrology of the receiving water body by reducing the lag time for delivery of the water and reducing the ability for the water to infiltrate into the ground. This can also affect water table elevations, base flows, and water quality. As a result, urbanization results in an increase in the “flashiness” of streamflows. The influence of urban runoff on Yellowstone River hydrology has not been quantified for this effort.

4.3.4.5 Climate Trends

It is difficult to accurately predict the influence of future climatic trends on Yellowstone River hydrology, because the body of literature available collectively describes a range of potential future conditions based on either historical trends or modeled future scenarios. Most available studies of historical trends indicate that precipitation and low flows have been on a decreasing trend. For example, one study indicates that at the outlet of Yellowstone Lake, mean August discharges have dropped by more than 25 percent since 1950 and these changes are influenced by climatic variables (Leppi, et al. 2012). Another study concluded that precipitation in the Yellowstone River basin has decreased by 10-20 percent since 1990 (IPCC, 1998). On a longer time frame, Swindell (2011) used tree ring analysis to show that, in the

Yellowstone River Basin, droughts pre-twentieth century were more severe in terms of duration and intensity than those that have occurred since.

As part of the development of a state water plan, Montana DNRC modeled a range of climate scenarios to estimate future shifts in temperature, precipitation and runoff. The results show that on a state-wide basis, virtually all model simulations project earlier runoff and reduced summer flows (Montana DNRC 2014). The anticipated shifts in timing would be the result of an earlier snowmelt and an increase in rain relative to snow during the late winter and early spring. Figure 4-51 shows the modeling results for the Yellowstone River at Billings (Montana DNRC 2014). Median daily hydrographs compiled for pre- and post-1990 data on the Yellowstone River at Livingston show the same trend; over the past 15 years, runoff has typically started about a week earlier and peaked 10 days earlier than it typically did between 1896 and 1990 (Figure 4-52).



Source: Montana DNRC, 2014

Figure 4-51 Median monthly flow modeling results for Yellowstone River at Billings under future and historical climate scenarios

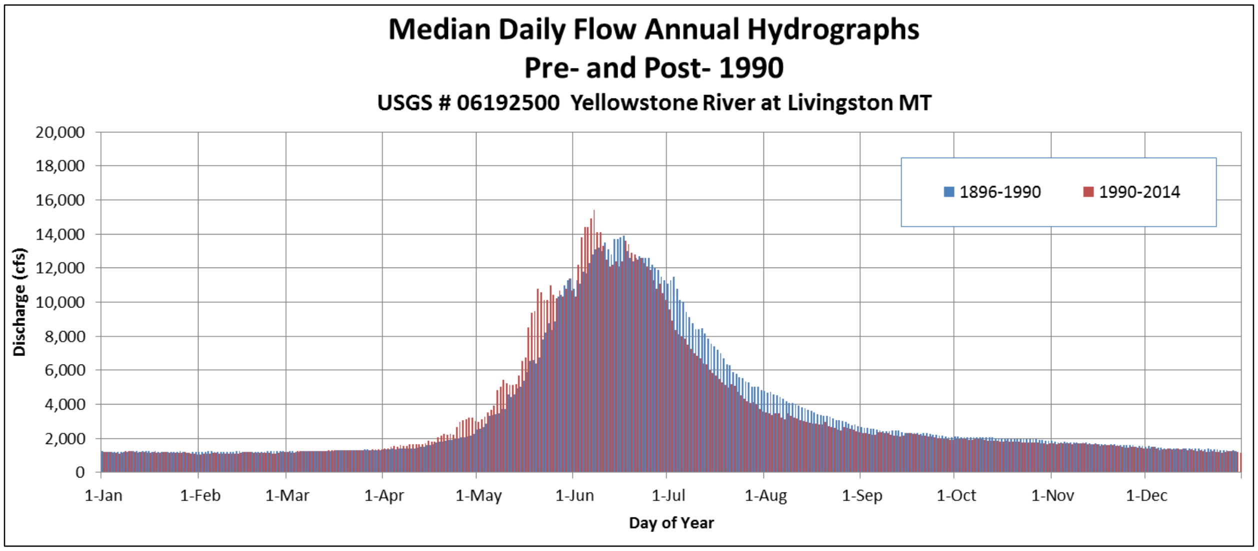


Figure 4-52 Pre- and post-1990 median daily hydrographs for Yellowstone River at Livingston showing recent shift to earlier runoff

4.4 Hydraulics: Floodplain Connectivity

The connectivity between a stream and its floodplain is becoming increasingly recognized as a critical aspect of long-term ecological function in river systems. Throughout the western United States, streams have become hydrologically disconnected from their floodplains due to a range of human impacts, including beaver trapping, channelization, flow alterations, dikes and levees, and excessive floodplain aggradation. Lost floodplain connectivity can cause a myriad of impacts, including changes in hydrology, ground water recharge rates, nutrient cycling patterns, riparian and wetland habitats, and the provision of refuge habitats for certain fish during floods. For the CEA study, hydraulic modeling techniques were used to evaluate how flow alterations and floodplain development have collectively altered the connectivity of the Yellowstone River to its floodplain. Areas of floodplain connectivity were identified using the one-dimensional HEC-RAS model, which is hydraulic software developed by the Corps of Engineers and commonly applied in floodplain boundary delineations.

The methodology used to characterize undeveloped and developed floodplain access requires consideration of both the flows in the river as well as the development status of the floodplain. To that end, two hydraulic models were developed and the results of those model runs were compared.

The processes used to assess changes in floodplain connectivity on the Yellowstone River due to human influences are:

1. Identify flood discharges for both undeveloped and developed conditions. These discharges reflect an undeveloped hydrologic regime (no withdrawals or impoundments), and the current hydrologic regime. The results of this analysis are described in Appendix 2 (Hydrology).
2. Develop a hydraulic model (HEC-RAS) that reflects the developed, modern floodplain.
3. Develop a second model to depict undeveloped conditions by removing all physical features, such as dikes, berms, and transportation encroachments.
4. Run the first model using undeveloped flows and undeveloped floodplain.
5. Run the second model using developed flows and developed floodplain.

6. Intersect the resulting maps of inundated area to identify those areas historically inundated by a given flow (e.g., 100-year flood) but currently disconnected.
7. Identify the apparent cause of disconnection for those areas no longer inundated, such as areas isolated by the Milwaukee Line railroad grade.
8. Summarize results to estimate the role of various land uses in isolating floodplain areas.

This approach was taken specifically for the 100-year floodplain. Additional assessment was performed on the modeling output for the 5- and 2-year floodplains to consider other issues such as land use development within frequently inundated areas and potential impacts on habitat within the active river corridor.

A detailed summary of this analysis and the results can be found in Appendix 3 (Floodplain Connectivity).

4.4.1 Summary of Findings

The primary findings of the hydrologic analysis that may support multiple aspects of the CEA include the following:

- Over 21,000 acres of 100-year floodplain area have been isolated between Springdale and the mouth of the Yellowstone River due to physical encroachments, land grading, and hydrologic alterations.
- The largest single contributing cause of floodplain isolation is reduced peak flows, which have isolated over 8,000 acres of the 100-year floodplain. The other primary causes are agricultural infrastructure and the active railroad line, which have isolated 3,720 and 3,526 acres, respectively.
- Areas where land uses have isolated 100-year floodplain tend to be concentrated in certain areas of the river corridor.
- Upstream of the Bighorn River confluence, typically less than 20 percent of the historical 5-year floodplain has been isolated. Downstream of the confluence, over 40 percent of the historical 5-year floodplain is now inaccessible by a 5-year flood.
- Currently, there are about 6,300 acres of irrigated land within the modern 5-year floodplain footprint (5,376 acres in flood irrigation and 871 acres under pivot irrigation).
- Isolation of the 2-year floodplain has resulted in reduced seasonal high flow channel activation during that event. Direct connectivity between side channels has been substantially reduced.
- The extent of 2-year floodplain isolation has been most significant between the mouths of the Bighorn and Tongue Rivers, where the developed 2-year floodplain footprint is on the order of 40 percent smaller than that under undeveloped conditions.

Table 4-4 summarizes those primary human influences that have affected floodplain access within the Yellowstone River corridor. With regard to land uses, the results indicate that there are multiple factors affecting floodplain access. Flow alterations, agricultural infrastructure, urban development, and transportation infrastructure have all affected the footprint of inundation for a given flow event. For all flows equal to or exceeding the 2-year flood, the area of floodplain inundated has decreased due to human influences.

4.4.2 General Processes Affecting Floodplain Access

Figure 4-53 shows an example of a reach with several identified causes of floodplain isolation. On the north side of the river valley, the abandoned Milwaukee line has isolated the undeveloped 100-year floodplain, and the modern rail line on the south side of the valley has similarly isolated historical floodplain against the valley wall. Within the active meander belt, floodplain has been isolated by flow alterations; these areas may also be affected by field grading.

The identified drivers of floodplain isolation include physical features and flow alterations. Physical features such as levees, dikes, and transportation embankments all have the potential to directly block floodplain access. These features may be associated with land uses including irrigation, transportation, urban/exurban development, and agriculture. In some cases, floodplain isolation has occurred on improved, leveled agricultural fields. In these cases, it is assumed that alterations in peak flow have isolated these areas from 100-year inundation, but it is acknowledged that agricultural development may have played a role due to field leveling and associated topographic alterations in flat terrain that is highly sensitive to slight changes in river stage.

Table 4-4
Summary of Human Impacts to Yellowstone River Floodplain Connectivity

Primary Human Influence	Specific Driver	Hydrologic Impact	Spatial Extent	Relative Impact to Floodplain Access
Hydrologic Alterations	Yellowtail Dam	Reduced Peak Flows	Below Bighorn	Major
	Consumptive Withdrawals: Irrigation	Reduced Flow	System-wide	Moderate
	Consumptive Withdrawals: Municipal and Industrial	Reduced Flow	Localized	Minor
Agriculture	Irrigation Ditches	Physical Isolation of Floodplain	Bighorn to Hysham	Moderate
	Levees and Dikes	Physical Isolation of Floodplain	Bighorn to Hysham, western Custer County	Moderate
Development	Urban Levees	Physical Isolation of Floodplain	Forsyth, Miles City, and Glendive	Major (Locally)
Interstate	I-90 Embankment	Physical Isolation of Floodplain	Billings	Moderate (Locally)
Active Railroad	MRL/BNSF Line	Physical Isolation of Floodplain	Below Billings; greatest impact between Billings and Hysham	Major
Abandoned Railroad	Milwaukee Line	Physical Isolation of Floodplain	Forsyth to Miles City	Major

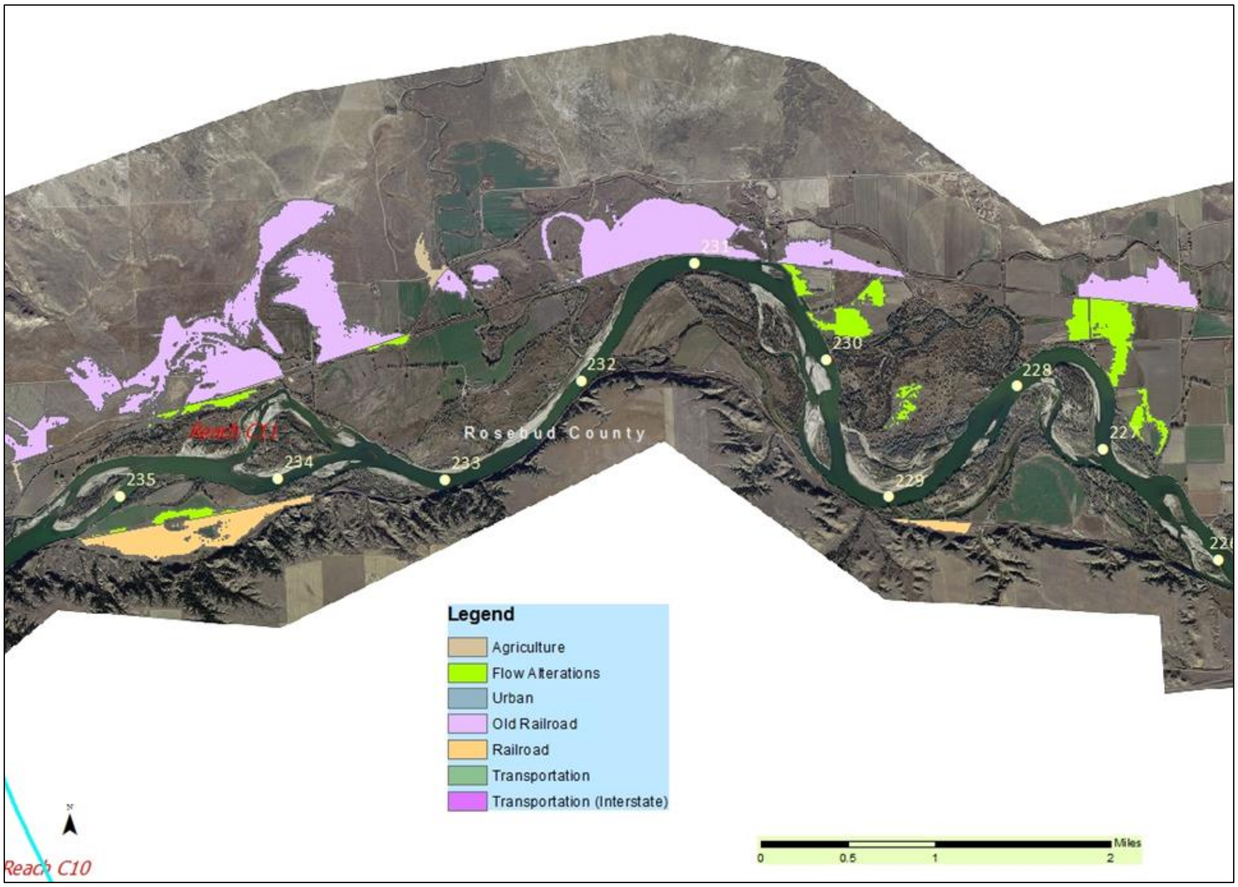


Figure 4-53 Example 100-year floodplain isolation polygons, Reach C11 below Forsyth

The reduction in peak flows on the river is a major contributor to floodplain isolation. Especially in areas where the historical floodplain is very broad and flat, small changes in flow can greatly change the area of ground inundated by a flood.

4.4.3 Total Extent of Floodplain Isolation in Yellowstone River Corridor

The influences of human development on floodplain connectivity were evaluated for the 100-, 5- and 2-year flood events. Table 4-5 summarizes the primary causes of floodplain isolation, areas of impact, and overall driver. For a more detailed description of the results of this evaluation, see Appendix 3 (Floodplain Connectivity).

4.4.3.1 Isolation of the Historical 100-year Floodplain

Development-related isolation of the 100-year floodplain on the Yellowstone River reflects either the influence of physical blockages such as dikes, levees, or transportation encroachments or the influence of an altered hydrologic regime on flow levels. Both impacts are apparent on the Yellowstone River 100-year floodplain. Table 4-6 and Figure 4-54 show the total extent of 100-year floodplain isolation within the river corridor in terms of cause. Based on the polygon analysis, a total of 21,437 acres of 100-year floodplain have been isolated from Springdale to the Missouri River (Park County was not included in the analysis).

Table 4-5
Summary of Main Locations and Causes of Floodplain Isolation

Cause of Isolation	Areas of Impact	Main Drivers
Hydrologic Alterations	Below Hysham	Yellowtail Dam impacts in broad valley
Urban/Exurban	Forsyth, Miles City, and Glendive	Urban levees
Railroad	Below Billings; greatest impact between Billings and Hysham	Direct isolation by active rail line
Abandoned Railroad	Forsyth to Miles City	Abandoned Milwaukee Line
Transportation (Roads, Highways, and I-90)	Billings	I-90
Agriculture		
Dikes and Levees	Bighorn to Hysham, western Custer County	Agricultural Levees
Irrigation Ditches	Bighorn to Hysham	Ditch Embankments

Table 4-6
Total Acreage of 100-year Floodplain Isolation

Impact	Floodplain Isolation (acres)
Hydrologic Alterations	8,604
Agriculture:	
Irrigation Ditch	1,388
Agricultural Levee/Riprap	2,331
Total Agriculture	**3,720**
Railroad	3,526
Abandoned Railroad	2,303
Transportation	2,054
Development	1,230
TOTAL	**21,437**

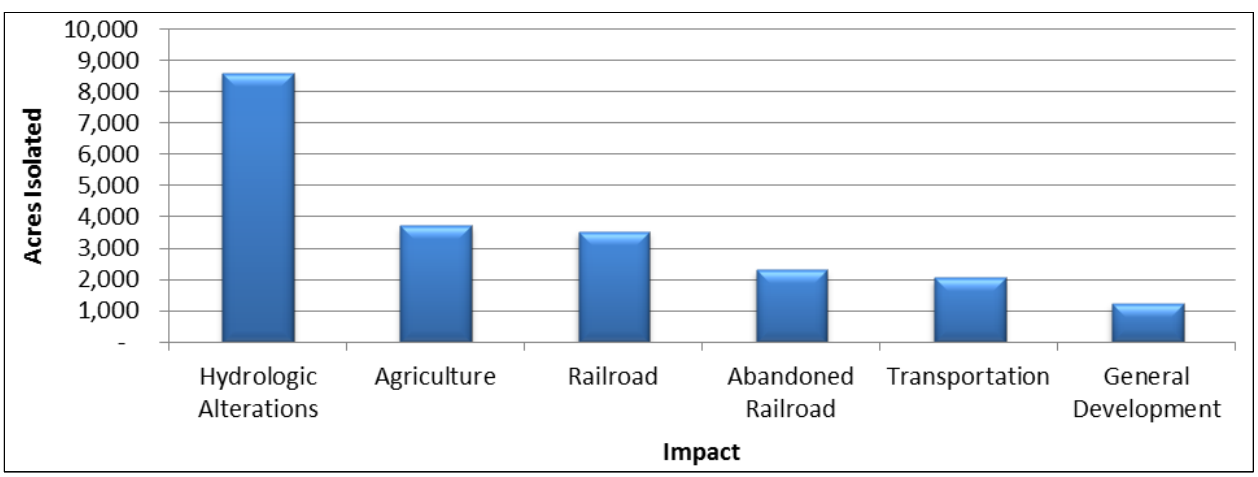


Figure 4-54 Total 100-year floodplain isolation by type of impact

The most extensive loss of 100-year floodplain area has occurred between Bighorn and Miles City, where over 10,000 acres of historical floodplain has been isolated from the river (Figure 4-55). Relatively high rates of cumulative floodplain loss also occur below Intake.

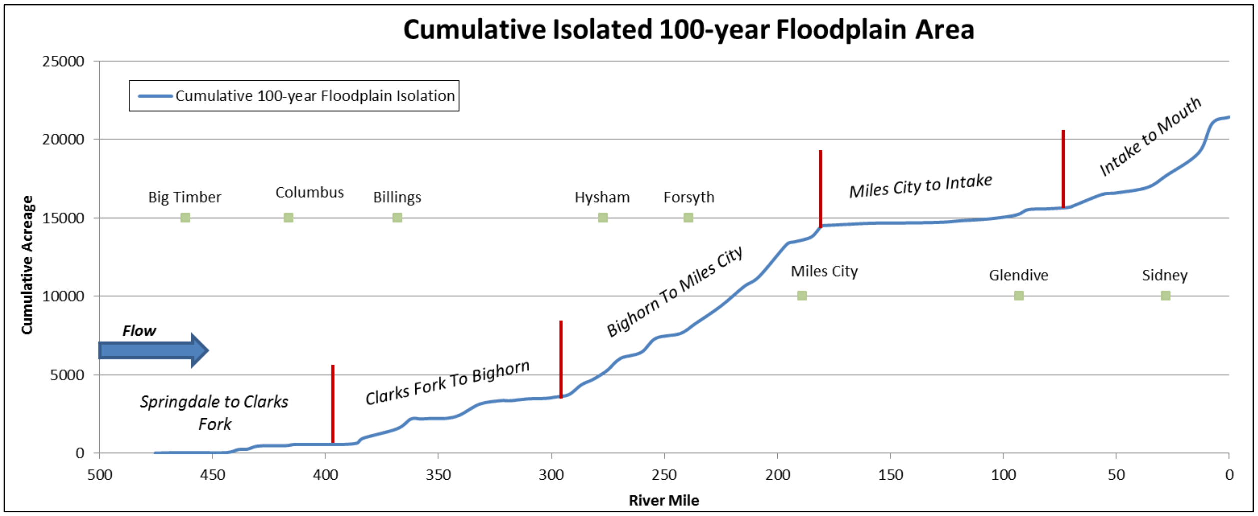


Figure 4-55 Cumulative floodplain isolation for all land uses

Figure 4-56 shows that with respect to each land use, the extent of floodplain isolation is concentrated in given areas. For example, transportation-related isolation is almost entirely occurring in the vicinity of Billings. Agricultural-related isolation is most common near Hysham and upstream of Miles City. Loss of floodplain due to the reduction in high flows is most pronounced where the river floodplain is especially broad, including the Mission and Hammond Valleys between Hysham and Forsyth, and from Sidney to the Missouri River confluence. Urban levees contribute to minor additional isolation of the floodplain, primarily at Forsyth, Miles City, and Glendive.

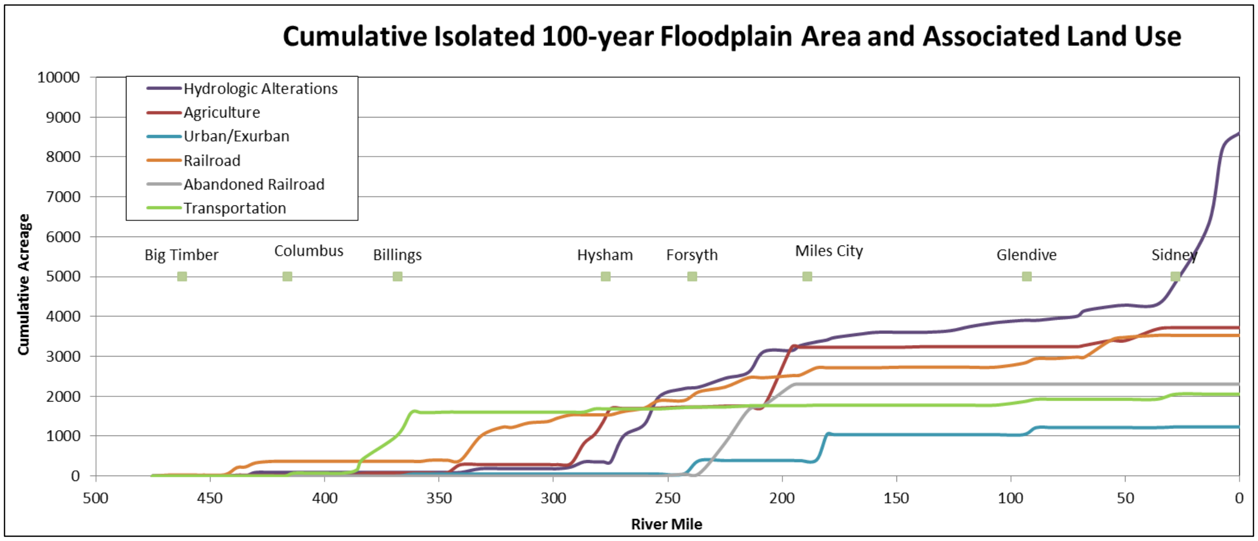


Figure 4-56 Cumulative floodplain isolation

Note: *Values accumulate in the downstream direction*

4.4.3.2 Isolation of the Historical 5-year Floodplain

The 5-year floodplain is that area which has a 20 percent chance of becoming inundated in any given year. This area reflects much more of the active riparian corridor than the 100-year floodplain, which has only a 1 percent chance of being inundated in any given year. When considering the percent loss of floodplain area, the 5-year floodplain has been isolated to a much greater extent than the 100-year floodplain (Figure 4-57 and Figure 4-58). Whereas approximately 5 to 20 percent of the 100-year floodplain has typically been isolated in any given reach, the 5-year floodplain area shows a 20 percent to 50 percent reduction in overall footprint between unregulated (undeveloped) and regulated (developed) conditions (Figure 4-59). The isolation of the 5-year floodplain has been most prominent downstream of the Bighorn River confluence (Figure 4-60).

As the 5-year floodplain has a relatively high frequency of inundation, development in this area is associated with substantial risk of flood damage. To that end, land uses in the 5-year floodplain have been summarized to estimate the type and extent of developed ground in these areas. Results show that much of the 5-year isolated floodplain area has been converted to irrigated agriculture (Figure 4-61). In total, there are over 17,000 acres of irrigated land in the historical 5-year floodplain. Although about 11,000 of those acres are in isolated floodplain areas, about 6,300 acres remain in the active 5- year floodplain footprint. Those fields within the active 5-year floodplain will be especially prone to flood inundation under relatively frequent flood events, as a “5-year flood” has a 20 percent chance of occurrence in any given year.

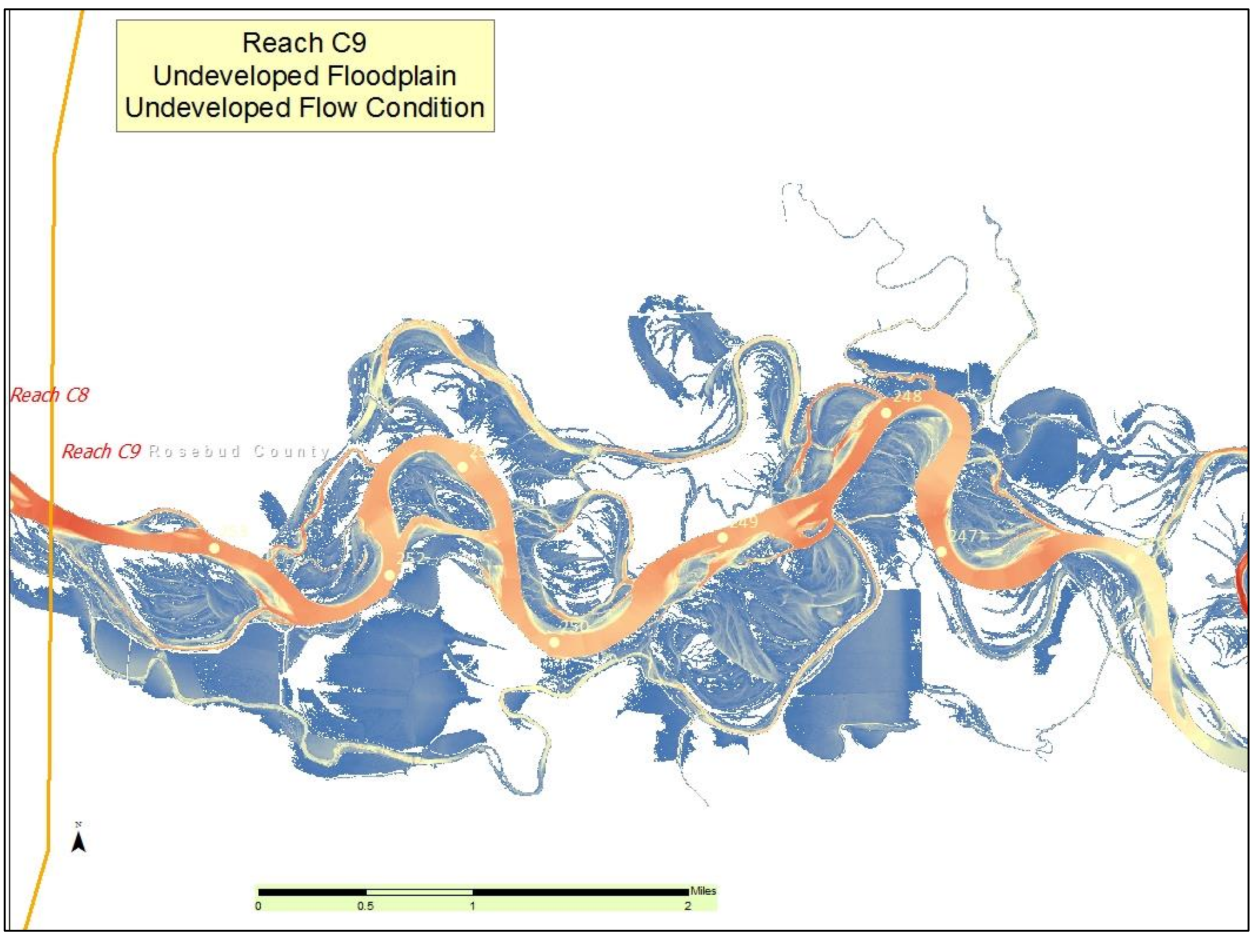


Figure 4-57 Reach C9 modeling results showing 5-year floodplain inundation and depth grids for undeveloped conditions

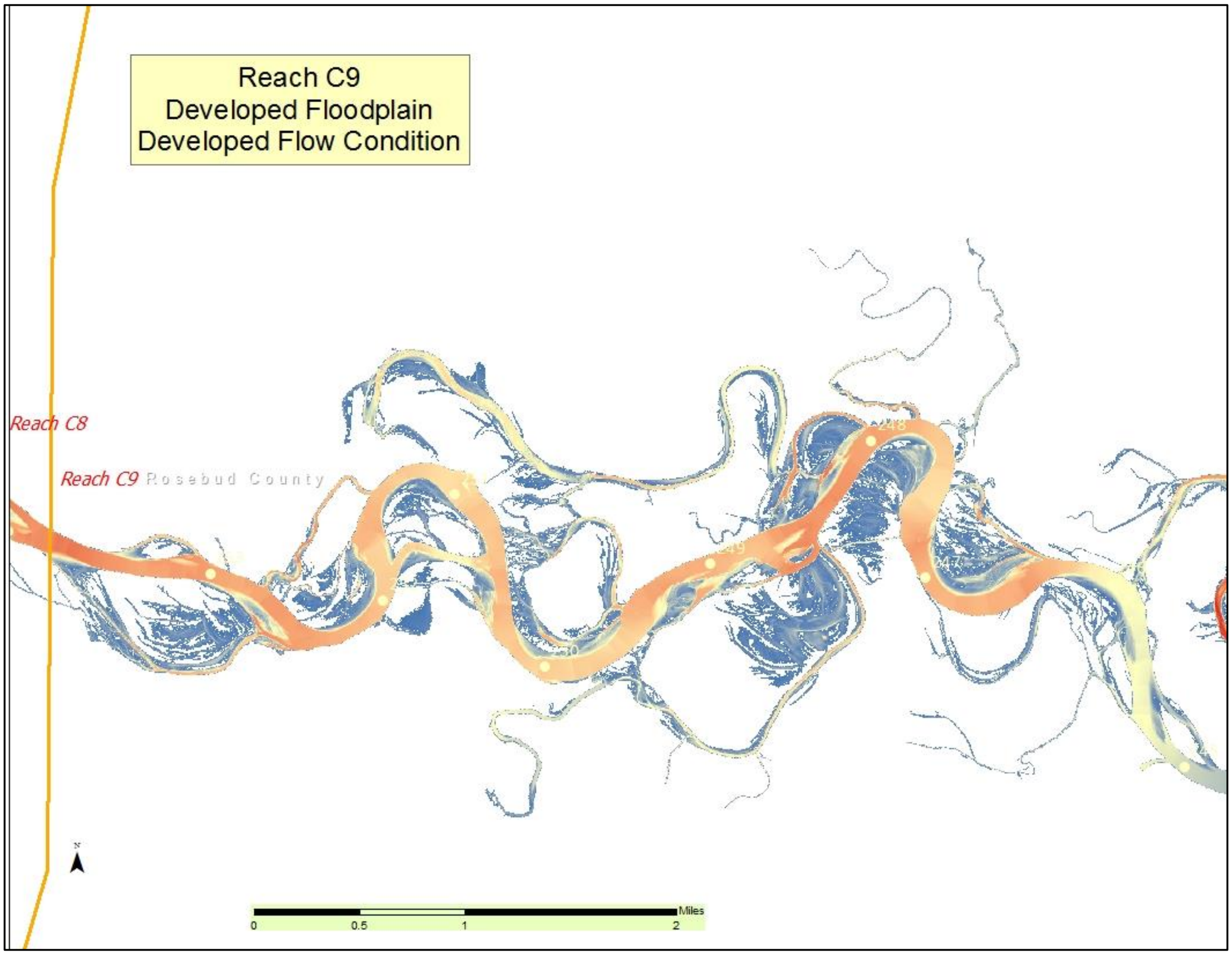


Figure 4-58 **Reach C9 modeling results showing 5-year floodplain inundation and depth grids for developed conditions**

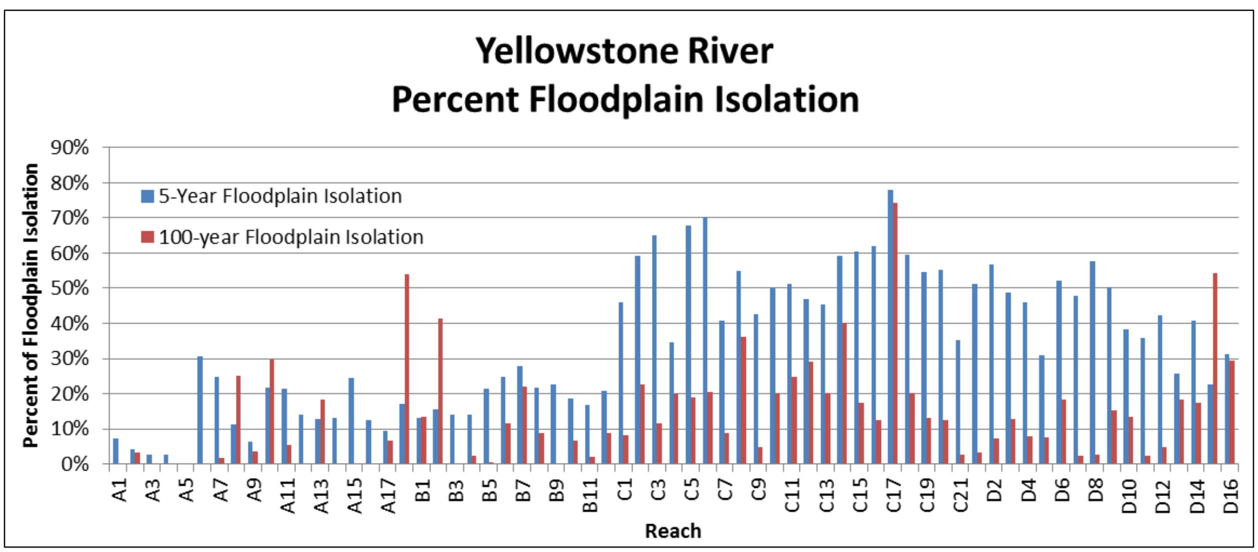


Figure 4-59 **Percent of 5- and 100-year floodplain isolation by reach**

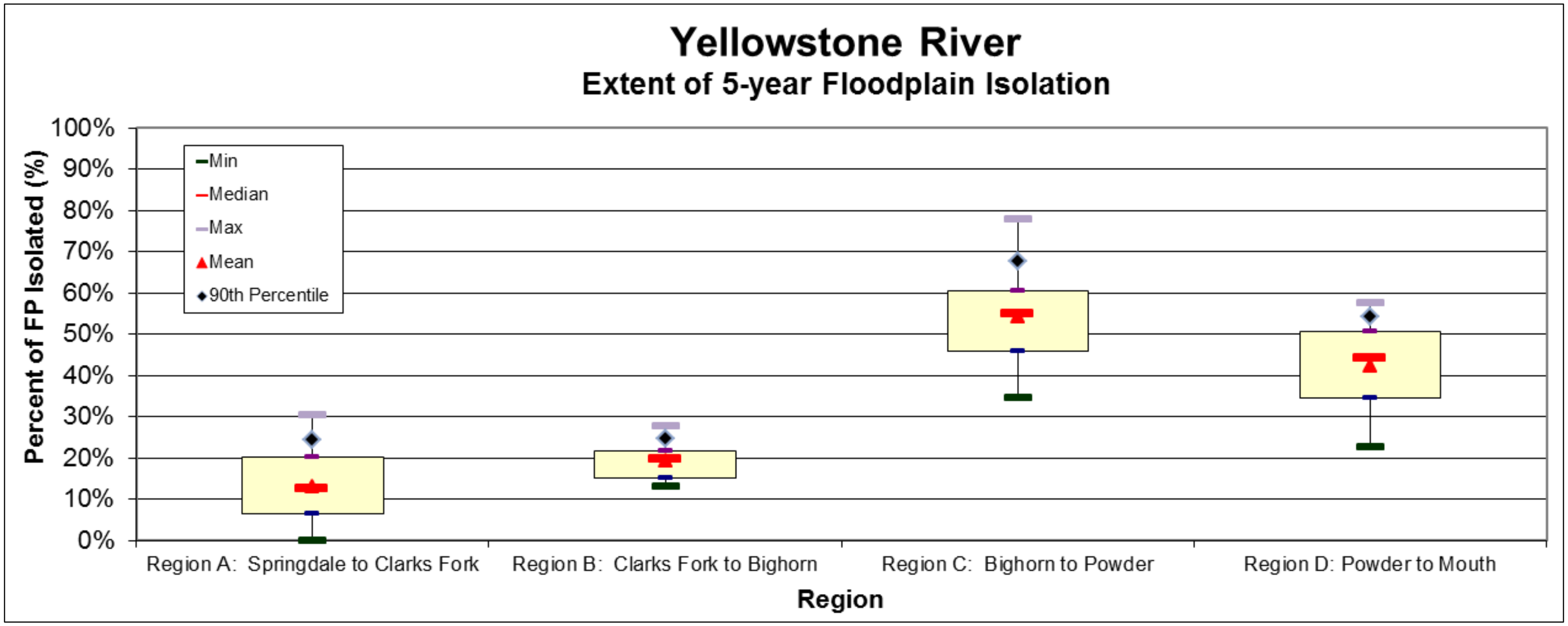


Figure 4-60 Statistical summary of 5-year floodplain isolation for all reaches within each region

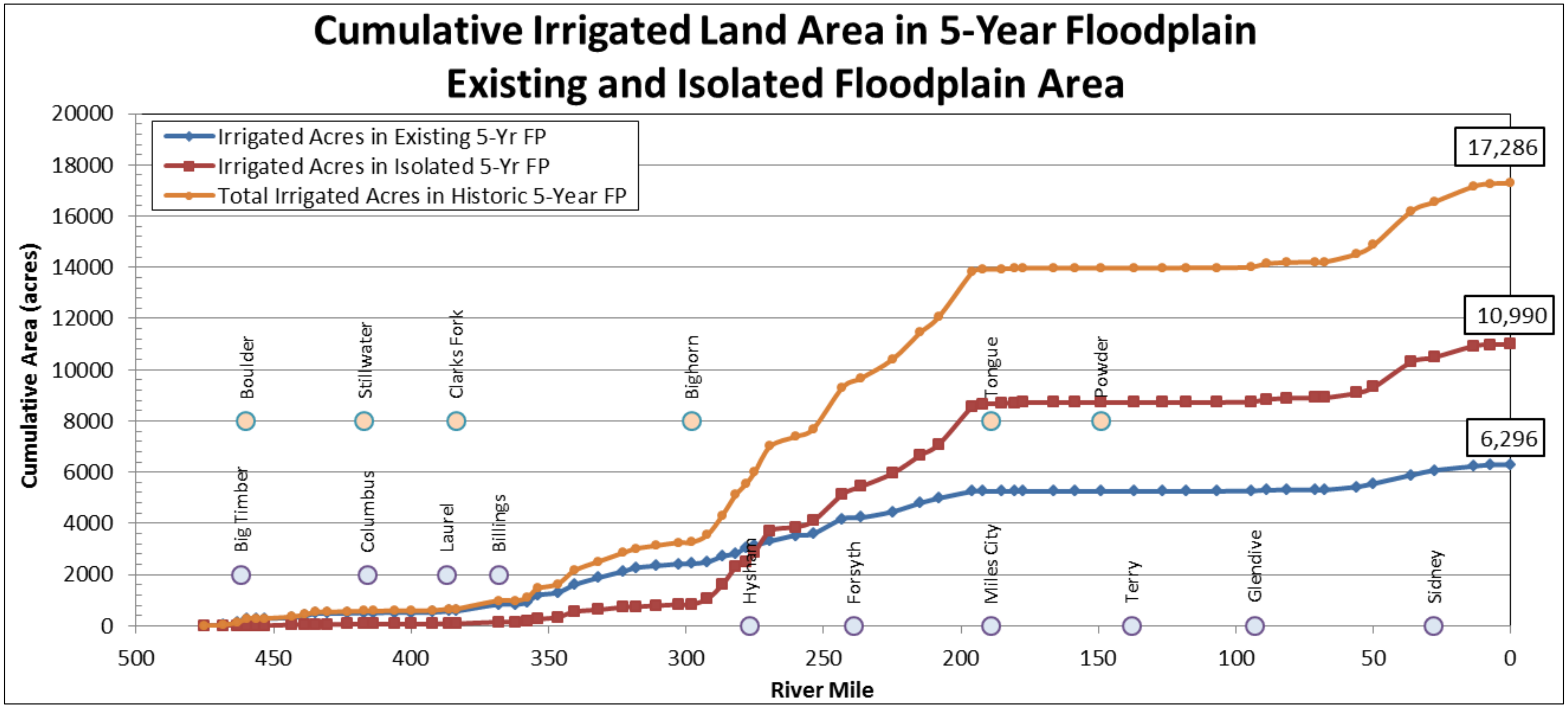


Figure 4-61 Cumulative irrigated acreage in both isolated and existing 5-year floodplain area

4.4.3.3 2-Year Floodplain Isolation

Figure 4-62 shows an example of the modeling results comparing the unregulated 2-year discharge on an undeveloped floodplain to the regulated 2-year discharge on a developed floodplain. Hydraulic modeling output for the 2-year event shows that the wetted width of the modeled cross sections has narrowed throughout the river corridor.

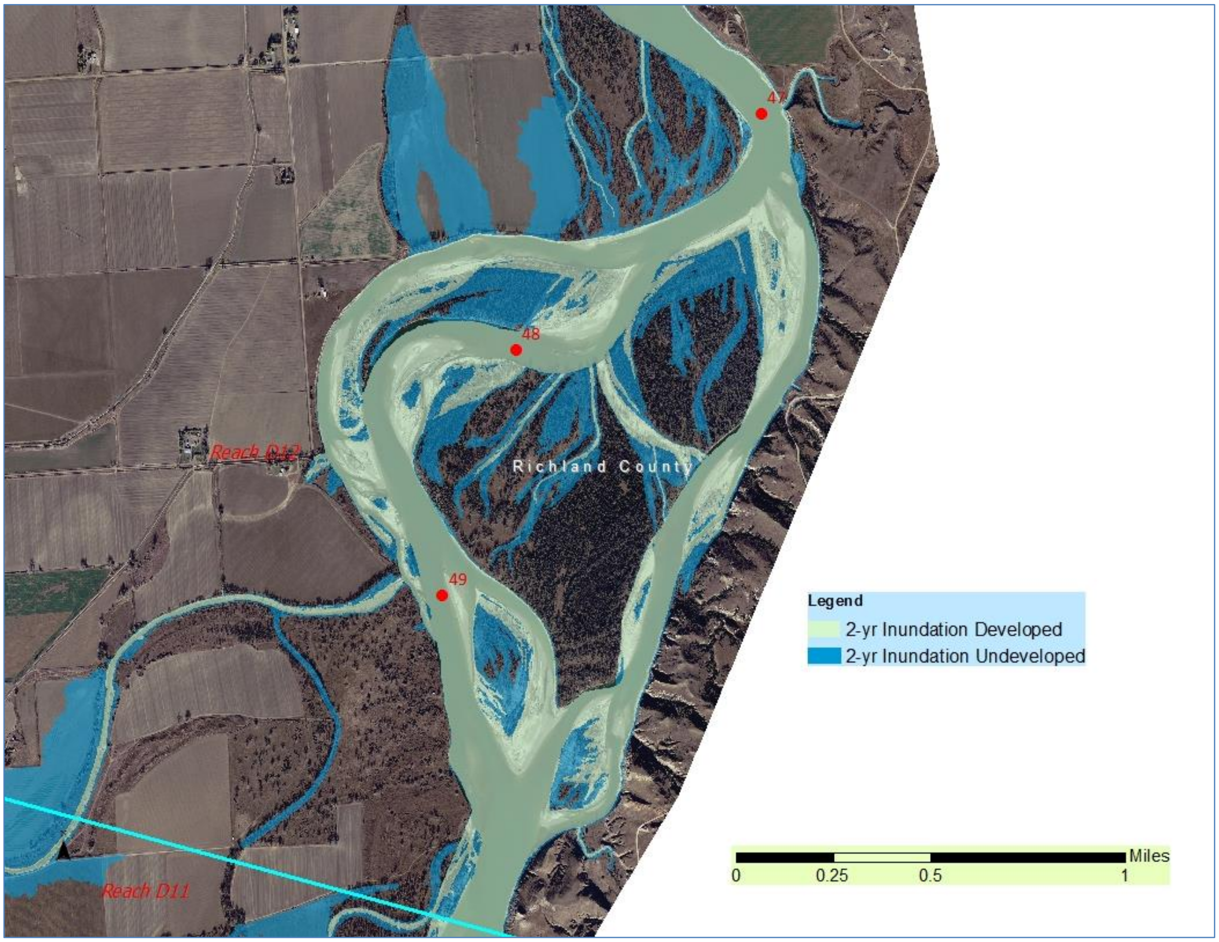


Figure 4-62 Hydraulic modeling results showing inundated area for 2-year undeveloped and 2-year developed conditions, Reach D12

On a reach-average basis, the most impacted areas are between the mouth of the Bighorn River and the mouth of the Tongue River, where the inundated area during a 2-year flood event has been reduced on the order of 40 percent (Figure 4-63). Other areas with a relatively high level of 2-year floodplain contraction include Laurel to Billings and downstream of Intake.

Figure 4-64 shows an example graphic of depth grid data developed by the Corps in support of fisheries work on the Yellowstone River. The results show that although much of the contraction in inundated area consists of relatively shallow flow, the connectivity between the main channel and dominant side channels has markedly reduced under developed conditions. This observation is purely visual, as changes in depths for given flow frequencies have not been quantified for this assessment.

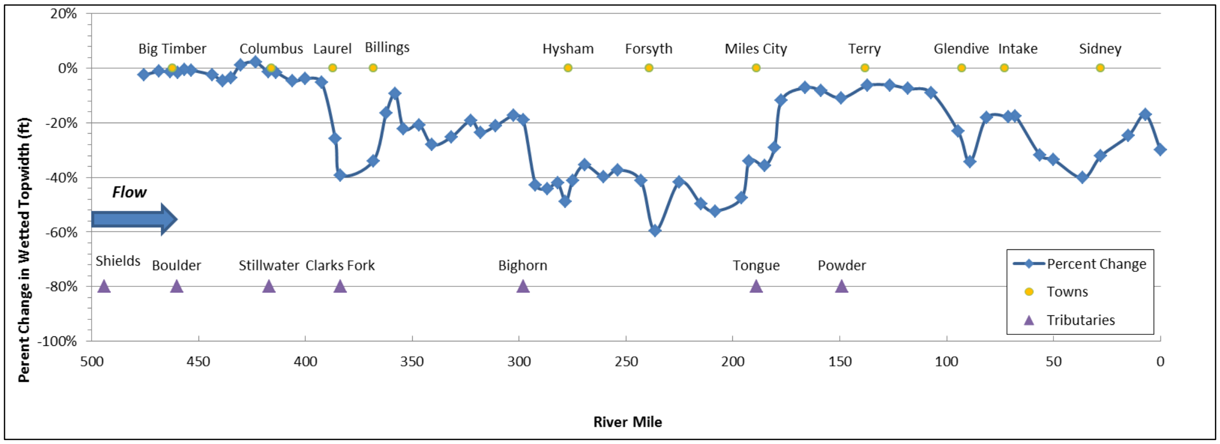


Figure 4-63 **Percent change in reach-averaged wetted top width between undeveloped and developed conditions, 2-year flood**

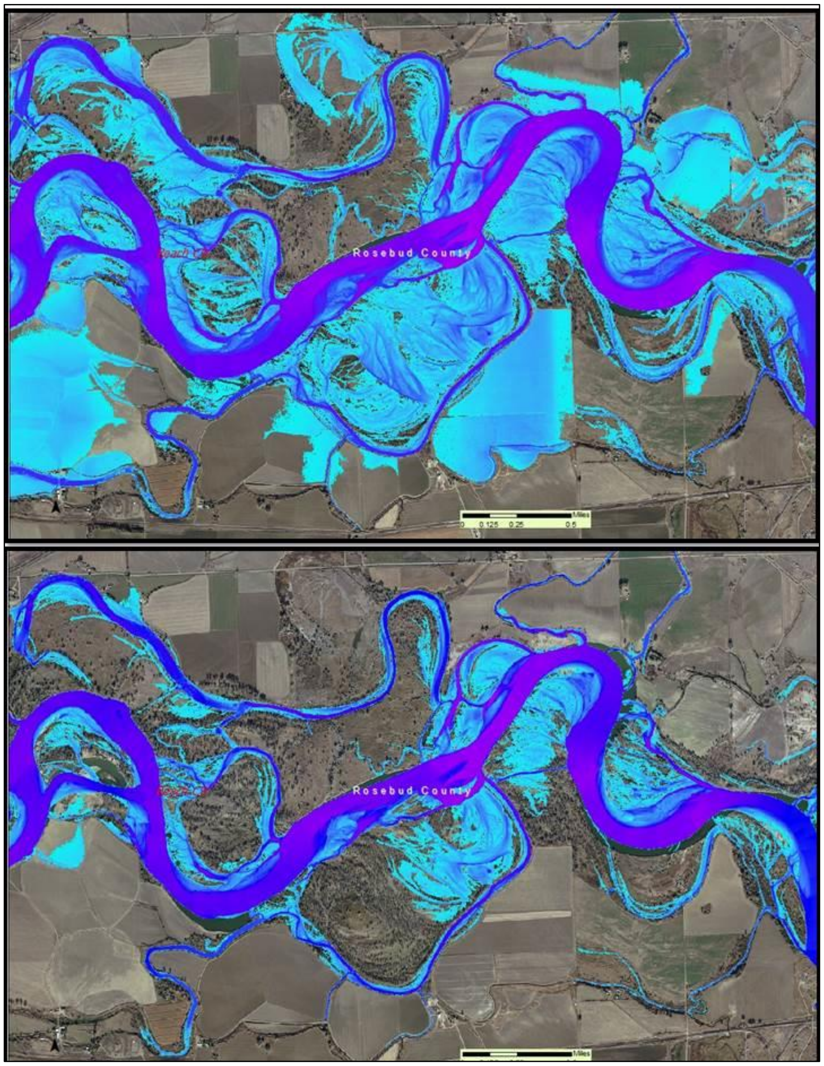


Figure 4-64 **Depth grid model output showing example 2-year relative inundation depths for undeveloped (top) and developed (bottom) conditions**

Note: *Example is an anabranching channel type in Rosebud County near Forsyth*

When summarized by channel type (Figure 4-65), the mean wetted top width values show that under undeveloped conditions the average inundated width at a 2-year flood increases from confined channel types (CM = "confined meandering") to less unconfined and partially confined channel types (UA = "unconfined anabranching"). This is likely reflective of the amount of overall floodplain area characteristic of each channel type. Under developed conditions, however, that overall variability is substantially reduced so that channel type has a much lower influence on overall 2-year floodplain access. This also indicates that the most affected channel types are those that are unconfined reaches.

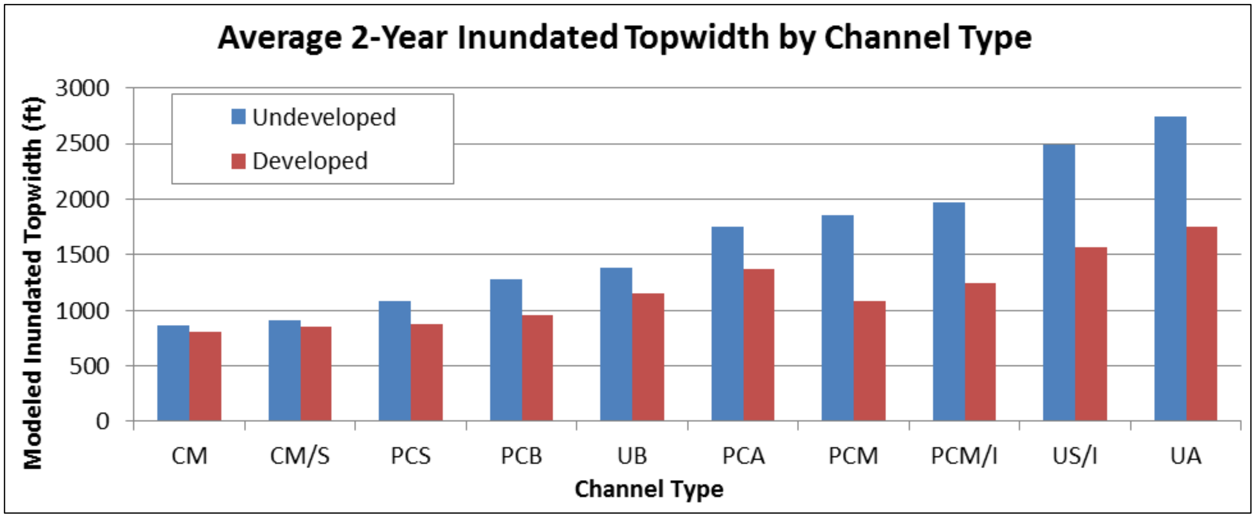


Figure 4-65 Mean reach inundated top width summarized by channel type for undeveloped and developed conditions

4.5 Geomorphology

4.5.1 Introduction

This section describes the extent and nature of primary human influences affecting the overall physical form and geomorphic processes of the Yellowstone River. Appendix 4 (Geomorphology) contains a summary of supporting documents, as well as the results of the data analysis performed in support of the CEA. Spatial and temporal alterations to the system geomorphology are described, with some discussion of the potential drivers of those changes. This section provides a synopsis of the technical information provided in Appendix 4 (Geomorphology), with further discussion of the potential role of individual drivers in affecting geomorphic process within the river corridor. Because of the complexity and magnitude of evaluating over five hundred miles of river, only selected geomorphic parameters are described in this report. These parameters have been selected as those that are supported by available data and those that show demonstrable change that is likely associated with human impacts. These parameters relate to patterns and changes in overall channel length, side channel length and connectivity, floodplain turnover rates, bank migration rates, and bankfull channel area. This section also describes the extents and types of bank armor mapped within the stream corridor.

4.5.2 Major Findings in Support of Cumulative Effects Analysis

The main alterations to the geomorphology of the Yellowstone River relate to human influences of side channel blockages, altered flow conditions, and bank armoring. As described in previous chapters, hydrologic analyses indicate that the most pronounced flow alterations are downstream of the mouth of the Bighorn River, indicating that Yellowtail Dam operations have exerted a major influence on the hydrology of the lower Yellowstone River. This in turn has affected river form and process below the confluence. Upstream of the Bighorn River confluence, changes in hydrology are less pronounced, yet geomorphic data indicate that these alterations also contribute to changes in river morphology. Bank armor is present throughout the river corridor and is most concentrated upstream of Miles City. Bank armor is likely the largest driver of geomorphic response on the river between Park City and the mouth of the Bighorn River. Physical blockages of side channels are present throughout the system.

Major findings of this assessment include the following:

- Since 1950, about 47 miles of side channel on the Yellowstone River have been blocked by physical features, typically small dikes. The blockages account for over 80 percent of the total side channel loss.
- Prior to 1950, 42 miles of side channel had already been blocked. As a result, a total of about 89 miles of side channel have been blocked by physical features on the river.
- The lower river has seen a major shift in gravel bar features; downstream of the Bighorn River confluence, the total extent of mid-channel bars has dropped by about 1,100 acres or 43 percent since 1950. Point bar area has also been reduced.
- In addition to loss of side channels and mid-channel bars, Regions C and D show a reduction of bankfull area in excess of 4,000 acres between 1950 and 2001.
- Floodplain turnover rates have dropped since the mid-1970s. Between Springdale and the Missouri River confluence (Park County Data were not available), the mean annual rate of total floodplain erosion dropped from 453 acres per year in 1955 to 1976 to 331 acres per year currently. Mean annual migration rates have dropped by over 20 percent in most reaches.
- One consequence of lower floodplain turnover rates is reduced recruitment of large woody debris; the post-1976 data show a reduction in the recruitment of closed timber areas by about 50 acres per year.
- Migration rates in the river corridor vary by land use. Over a 25-year period, banks eroded into hay ground and irrigated ground an average 40 to 50 feet further than through multiple use ground (multiple use refers to non-irrigated agricultural land that is adjacent to active agricultural production. For example, the corners of a field serviced by pivot irrigation). Every region shows this fundamental trend of increased rates of migration through hay/pasture land and ground irrigated by sprinkler or flood.
- As of 2011, there was approximately 136 miles of bank armor on the Yellowstone River below Gardiner, including rock riprap, flow deflectors, concrete riprap, car bodies, and minor extents of other techniques such as gabions and steel retaining walls. Rock riprap comprises 75 percent of the total armor. Between 2001 and 2011, about 13 miles of armor was constructed on the river; the 2011 flood also caused failure of at least four miles of armor, most of which was concrete rubble and flow deflectors.

Table 4-7 shows a summary of specific human influences described in this section, along with the associated impact, spatial extent of that impact, and relative magnitude of the impact. Although there are additional factors that will affect the system geomorphology, such as small channelization projects and bridge construction, these drivers are not considered in detail due to either a lack of data or their relatively small overall impact on river process.

Table 4-7
Summary of Human Impacts on Yellowstone River Geomorphology

Human Influence	Geomorphic Impact	Spatial Extent	Relative Impact to Geomorphology
Altered Hydrograph	Reduced bankfull area	Regions C and D	Major
	Abandoned side channels	System-wide	Major
	Reduced migration rates	System-wide	Major
	Reduced large woody debris (LWD) recruitment	System-wide	Major
	Reduced floodplain turnover	Regions A-D	Major
	Loss of mid-channel bars	Regions C and D	Major
	Increased bank erosion	Region C	Uncertain
	Increased tributary destabilization where flows are augmented by storm water or agricultural runoff	System-wide	Uncertain
	Increased winter bank erosion	Below Bighorn Confluence	Uncertain
Physical Isolation of Floodplain and Side Channels	Active abandonment of side channels	System-wide	Major
	Localized flow concentration and downcutting	System-wide	Uncertain
Land Use Conversions	Altered migration rates	Regions A-D	Moderate
	Reduced LWD recruitment	System-wide	Moderate
	Increased Bank Armor	System-wide	Major
Bank Armor	Reduced rates of bank migration, floodplain turnover, and LWD recruitment	System-wide	Major
	Local downcutting	Areas of high density of armor	Uncertain
	Reduced mid-channel bar extent	Uncertain	Uncertain
Altered Sediment Regime	Downcutting	Uncertain	Uncertain
	Reduced mid-channel bar extent	Regions C and D	Moderate to Major
Saltcedar Invasion	Reduced rates of migration, channel narrowing	All areas of invasion (lower river)	Uncertain

4.5.3 Summary of Results: Geomorphic Change on the Yellowstone River

The following section summarizes a series of geomorphic changes that have been documented in the river corridor. These changes generally reflect the conversion of the river from a large and very dynamic river to a less dynamic river with a smaller total footprint. A myriad of human influences can contribute to a given geomorphic response, so the goal is to try to identify the dominant cause-and-effect relationships that are evident from available data. Those cause-and-effect relationships are summarized in Table 4-7.

The types of changes observed include general trends of side channel loss, loss of mid-channel bars, reduced channel size, reduced floodplain turnover rates, and reduced migration rates. These changes are associated with reduced flow magnitudes, floodplain features, land use conversions, bank armor, altered sediment regimes, and potentially the influence of invasive species such as saltcedar.

4.5.3.1 Loss of Anabranching Channel Length (Bankfull Side Channels)

Anabranching channels are those side channels that are separated by the river by substantial islands (areas that support woody vegetation), and as such create split flow patterns at bankfull flow.

In the 1950s, there were approximately 508 miles of anabranching channels in the Yellowstone River below Gardiner. By 2001 there were a total of 463 miles of anabranching channel. When plotted as cumulative change in the downstream direction, the anabranching channel datasets indicated that since 1950, more than 50 miles of anabranching channel length has been lost between Livingston and Miles City (Figure 4-66). Between Miles City and Sidney, the cumulative rate of loss has been much slower, and downstream of Sidney the length of anabranching channel has increased over 10 miles. This increase in anabranching channel length below Sidney reflects vegetation encroachment onto mid-channel bar deposits since 1950, which converted secondary channels around gravel bars into anabranching channels around forested islands.

The majority of the lost anabranching channel length can be attributed to physical blockages, typically small dikes. These blockages account for over 80 percent of the total loss in total side channel length (Figure 4-66). About 47 miles of side channels have been blocked since 1950 by constructed floodplain dikes. The remainder of side channel loss was likely natural abandonment or passive abandonment due to reduced flows

Side channels were also blocked prior to 1950. At that time, about 42 miles of side channels had already been blocked by small dikes. In total, about 89 miles of side channels have been mapped as blocked by dikes on the Yellowstone River. These channel blockages extend throughout the entire river corridor (Figure 4-67).

4.5.3.2 Reduced Secondary Channel Length (low flow channels) and Loss of Mid-Channel Bars

Low flow channels, commonly referred to as “secondary channels,” are those that flow around open gravel bars. They were evaluated in Regions C and D (Bighorn to the Missouri River) where low flow aerial imagery was available, and where flows were very similar when the air photos were taken (Appendix 4 (Geomorphology)). In these areas extending from the mouth of the Bighorn River to the Missouri River confluence, the Yellowstone River has lost about 40.2 miles of secondary channel length between 1950 and 2001. Most of this loss occurred between Hysham and Forsyth and below Glendive (Figure 4-68). These changes were accompanied by a major shift in the types of in-stream bar features in the lower river; in Reaches C and D the total extent of mid-channel bars has dropped by about 1,100 acres or 43 percent since 1950 (Figure 4-69). Point bar area has also been reduced. There has been a net gain of bank attached bar area, indicating a conversion of gravel bars in the middle of the river to gravel bars that are against the riverbank at low flow. This has major implications for aquatic habitat, as the conversion to bank-attached bars indicates fewer inundated side channels for aquatic species, and increased access to gravel bars by land animals that predate on birds that nest on open gravel bars.

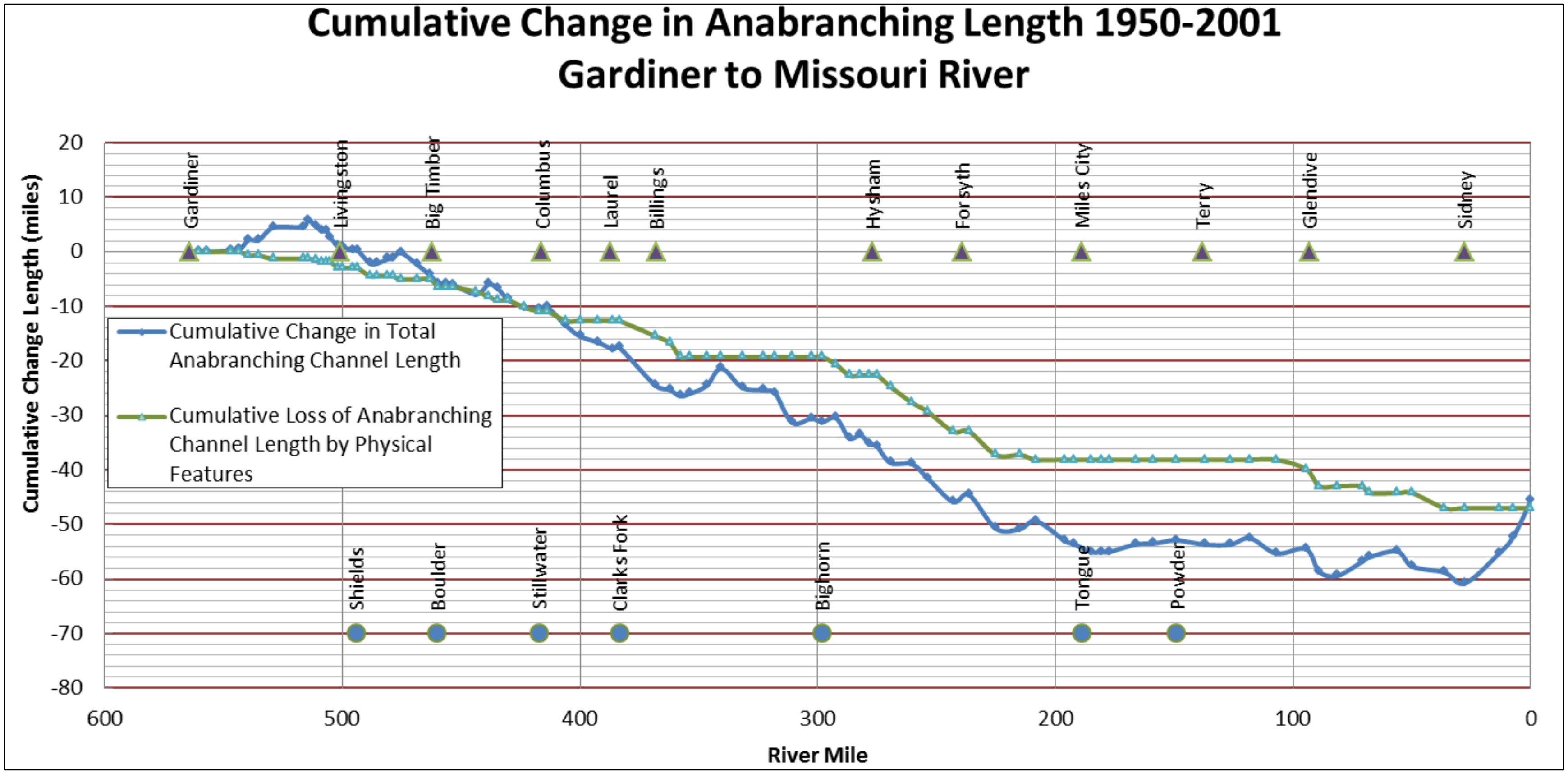


Figure 4-66 **Cumulative 1950-2001 loss of anabranching channel length and cumulative isolation of side channels by physical features**

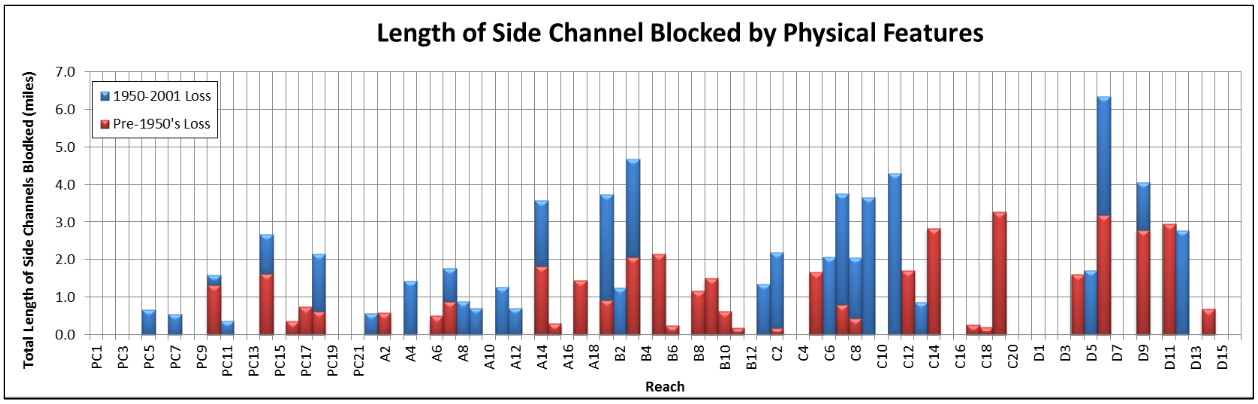


Figure 4-67 **Total side channel loss due to blockages, pre- and post-1950s**

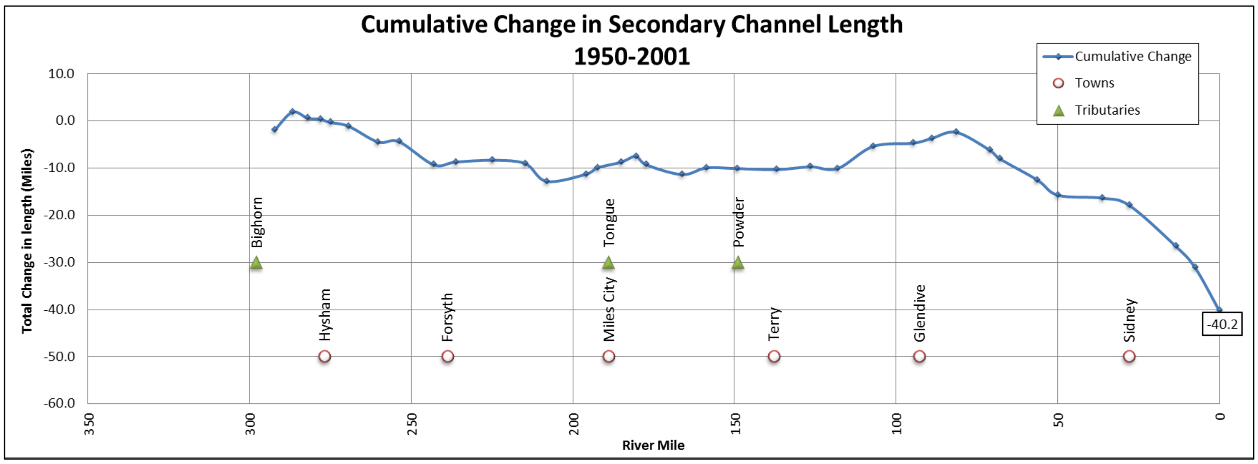


Figure 4-68 **1950-2001 cumulative change in secondary channel (Bighorn River confluence to mouth)**

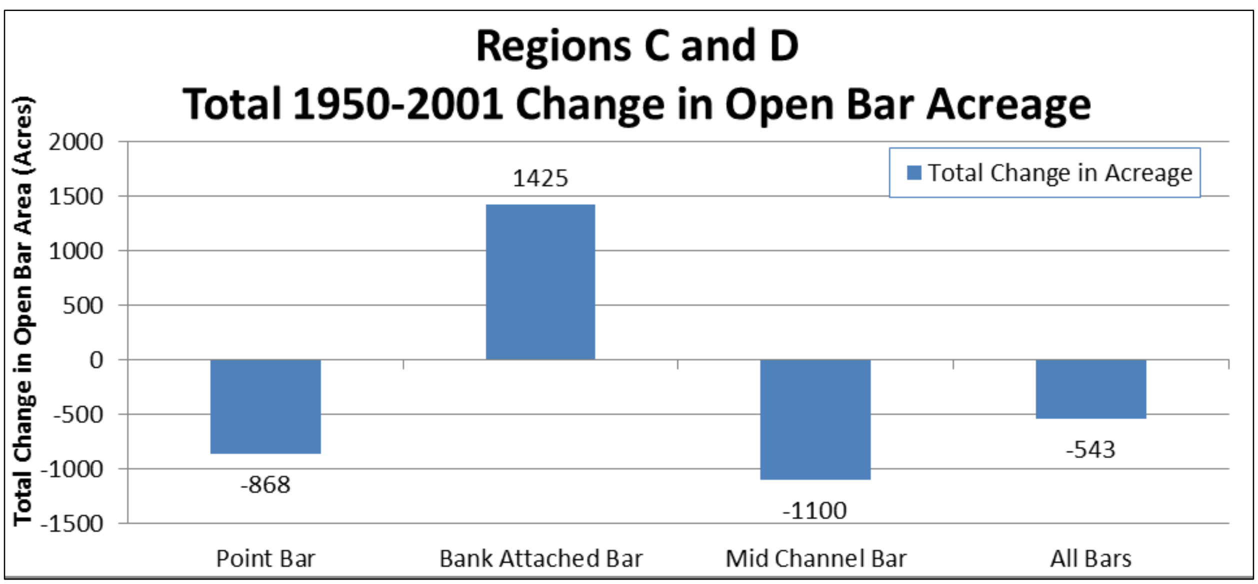


Figure 4-69 **Total change in extent of open bar types, 1950-2001**

4.5.3.3 Reduced Bankfull Channel Area

Digitized banklines of the active channel margin were used to estimate the total bankfull channel area for each reach through time. Demonstrated changes in channel area depict general trends in the overall size of the river and were not correlated to specific discharges. Upstream of the Bighorn River, the total channel area as measured on air photos has been reduced by 1,760 acres between 1950 and 2011. Downstream, however, the trend is reversed; there was a net loss of 4,460 acres between the Bighorn River confluence and the mouth. When plotted by individual timeframe for Regions A-D (Park County data were not available for all time steps), the continual loss of bankfull area below the Bighorn River is evident (Regions C and D; Figure 4-70).

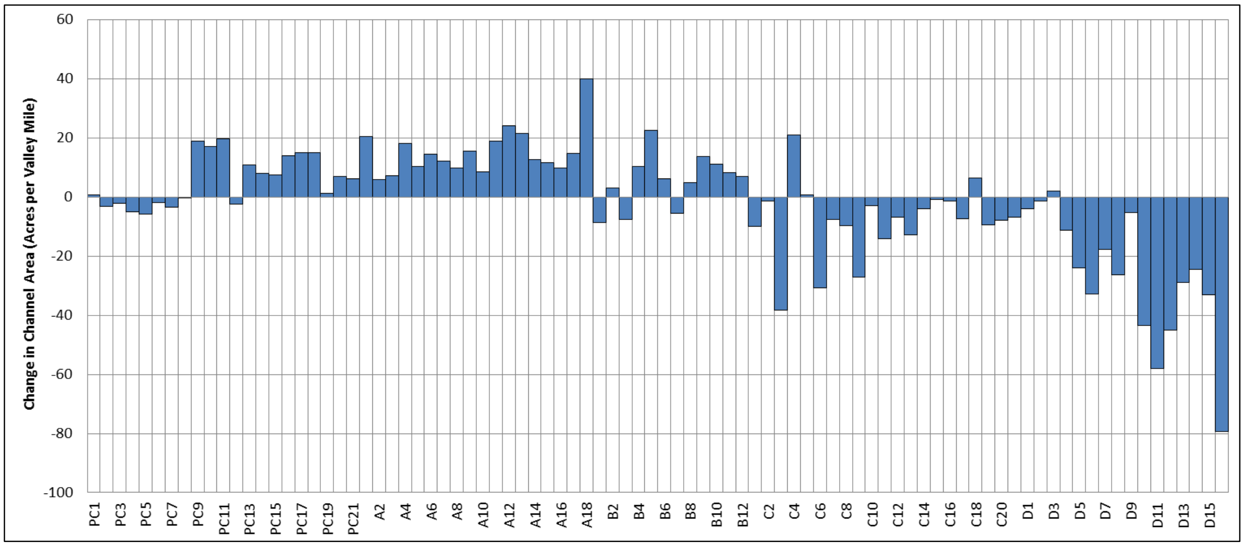


Figure 4-70 Total change in bankfull channel area by reach, 1950s-2001

Upstream of the Bighorn River, the consistent gain in bankfull area combined with a net loss of anabranching channels indicates that the primary channel has enlarged since 1950. Much of this enlargement occurred between 1995 and 2001 (see Figure 4-71) and may relate to the 1996 and 1997 floods, which were concentrated in the upper river. With the reduction in anabranching channels in Regions A and B, it appears that there was a net gain in overall channel footprint, indicating expansion of the main thread that exceeded the lost side channel area. Downstream in Regions C and D, the channel contraction is more affected by a reduction in channel forming flows.

4.5.3.4 Reduced Floodplain Turnover Rates and LWD Recruitment

Floodplain turnover rates have dropped in Regions A through D since the mid-1970s. Between Springdale and the Missouri River confluence (Park County Data were not available), a comparison of the 1950 to 1976 and 1976 to 2001 timeframes show that whereas the 26 years in the pre-1976 time period was characterized by the erosion of 11,781 acres of floodplain, the subsequent 25 years saw the erosion of 8,285 acres. Annualized data indicate that the mean annual rate of total floodplain erosion dropped from 453 acres per year to 331 acres per year (Figure 4-72).

One consequence of lower floodplain turnover rates is reduced recruitment of large woody debris (LWD); the post-1976 data show a reduction in the annual recruitment rate of closed timber areas by about 56 acres per year. Flow alterations on the Bighorn River have also reduced the rate of large wood recruitment from that system to the Yellowstone River (M. Ruggles, MFWP, personal communication).

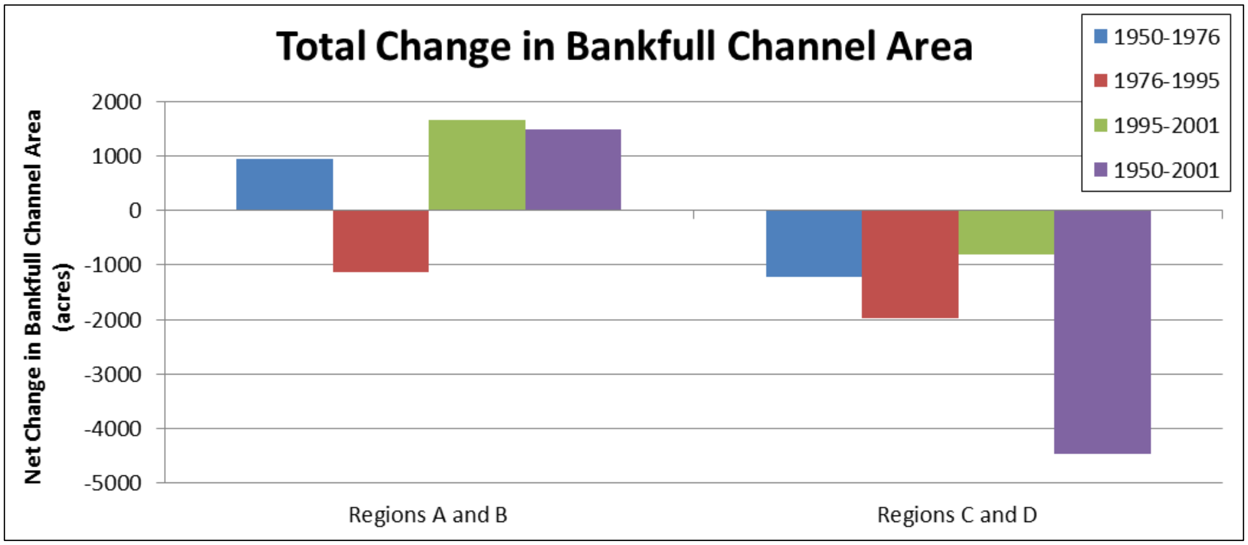


Figure 4-71 **Total change bankfull channel area by timeframe**
Note: *Data are not available for Park County*

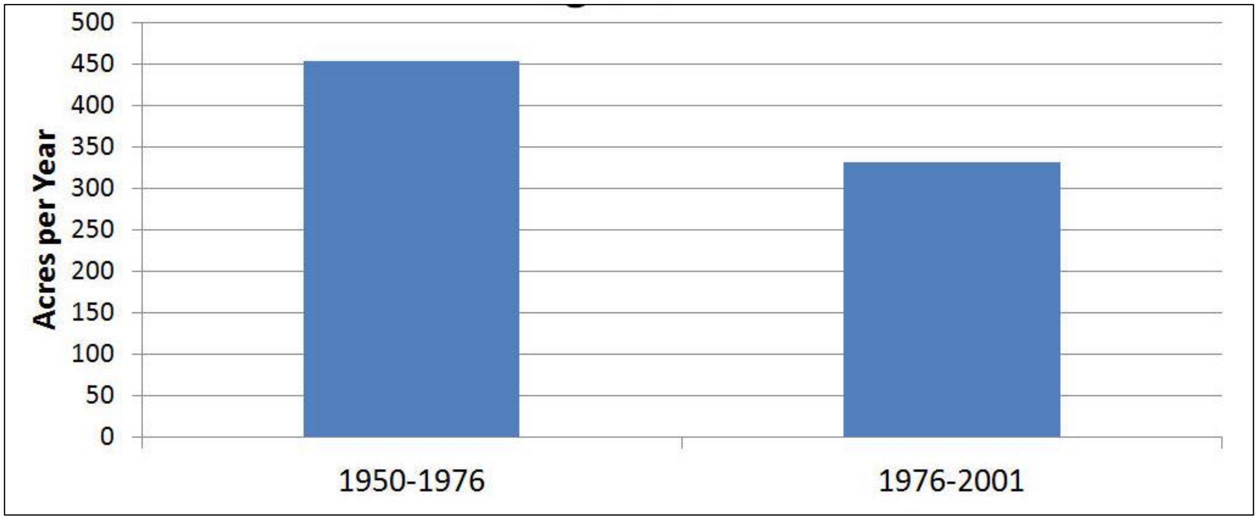


Figure 4-72 **Annualized rate of floodplain turnover by timeframe, Regions A – D**

4.5.3.5 Reduced Migration Rates

Measurements of non-armored bank migration indicate that there has been a river-wide reduction in average rates of bankline movement pre- and post-1976. Mean annual migration rates have dropped by over 20 percent in most reaches below Springdale (Figure 4-73 and Figure 4-74), although Park County does not show any clear trend. Upstream of the Bighorn confluence, reach-scale mean migration rates have dropped from an average of 6.4 feet per year to 5.3 feet per year. Downstream of the Bighorn confluence, rates have dropped from an average of 8.7 feet per year to 4.9 feet per year

Migration rates in the river corridor vary by land use. Every region shows a trend of increased rates of migration through hay/pasture land and ground irrigated by sprinkler or flood that are easily erodible, and the trend is most distinct in Regions B through D (Figure 4-75).

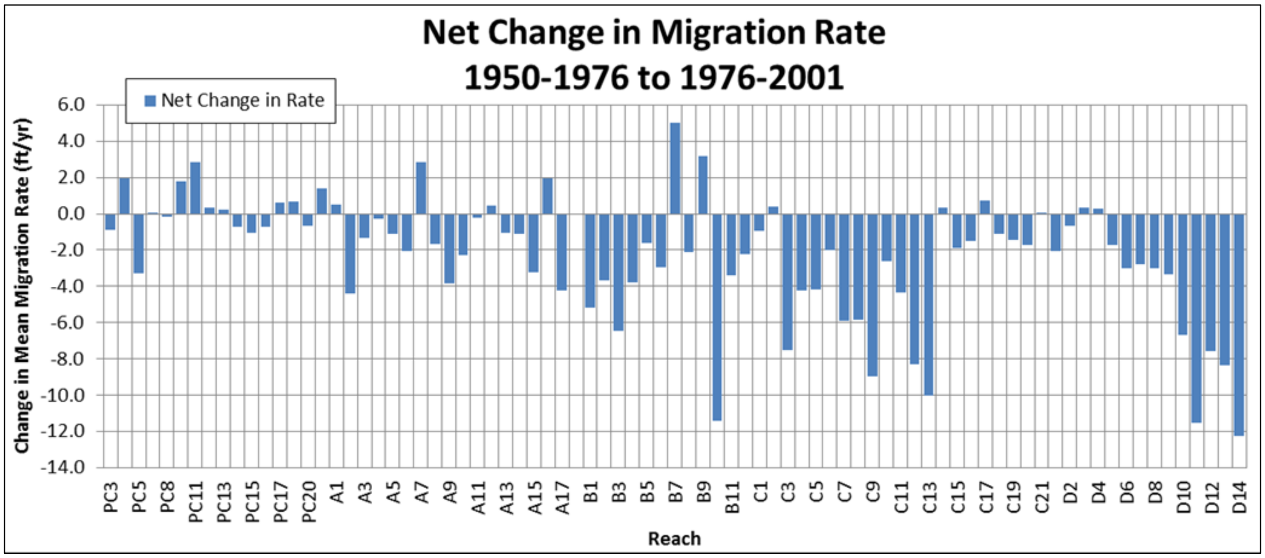


Figure 4-73 **Net change in average annual migration rate pre- and post- 1976**

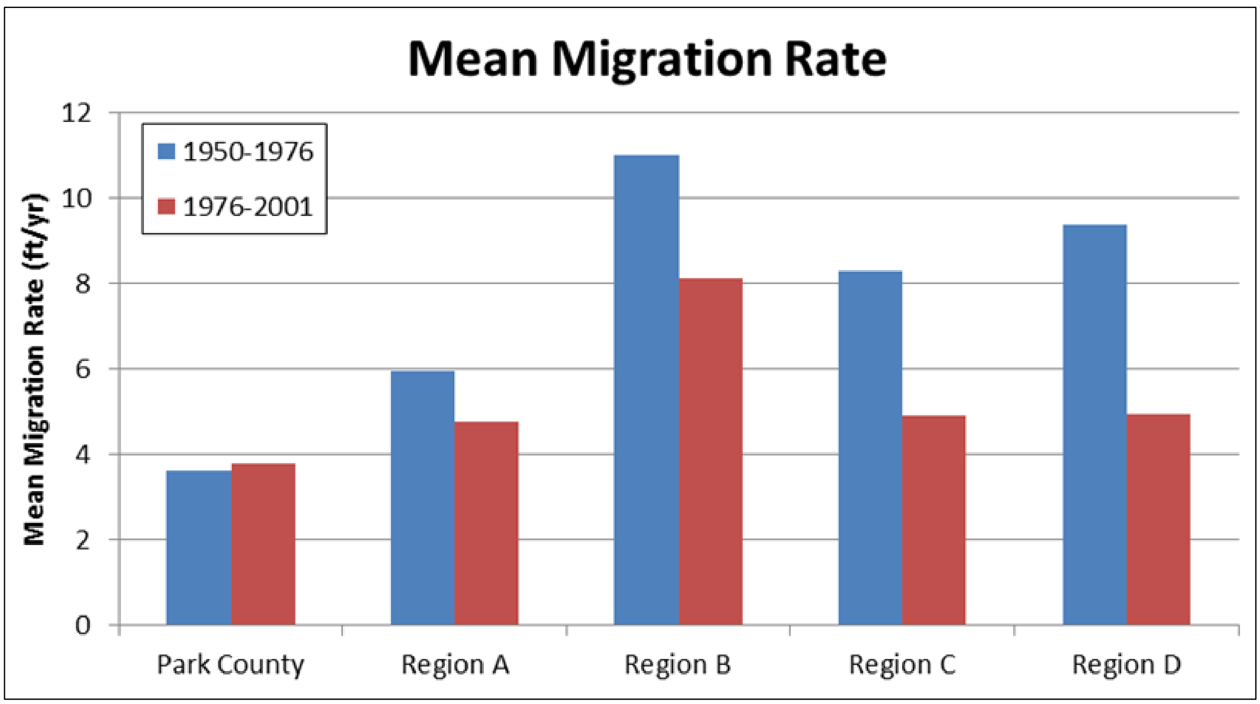


Figure 4-74 **Mean reach-average migration rates by Region**

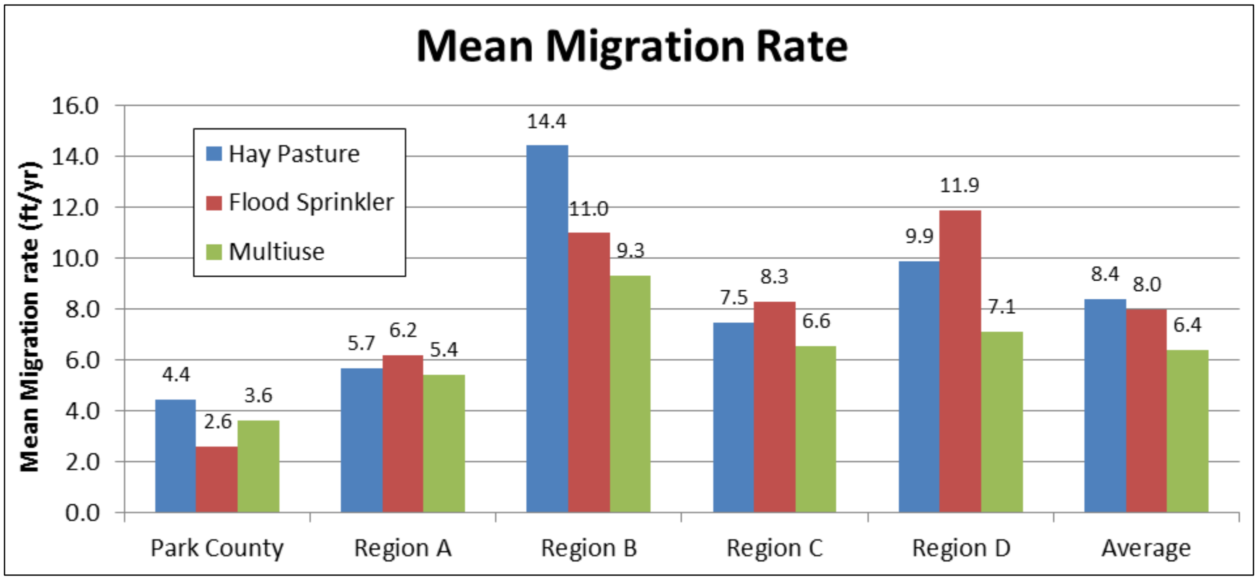


Figure 4-75 Mean migration rate for selected agricultural land uses summarized by region

4.5.3.6 Expansion of Bank Armor

As of 2011, there was approximately 136 miles of bank armor on the Yellowstone River below Gardiner, including rock riprap, flow deflectors, concrete riprap, car bodies, and minor extents of other techniques such as gabions and steel retaining wall (Figure 4-76). Rock riprap comprises 75 percent of the total armor (Figure 4-77).

Between 2001 and 2011, about 13 miles of armor was constructed on the river. The 2011 flood also eroded behind at least four miles of armor, most of which was concrete rubble and flow deflectors (Figure 4-78).

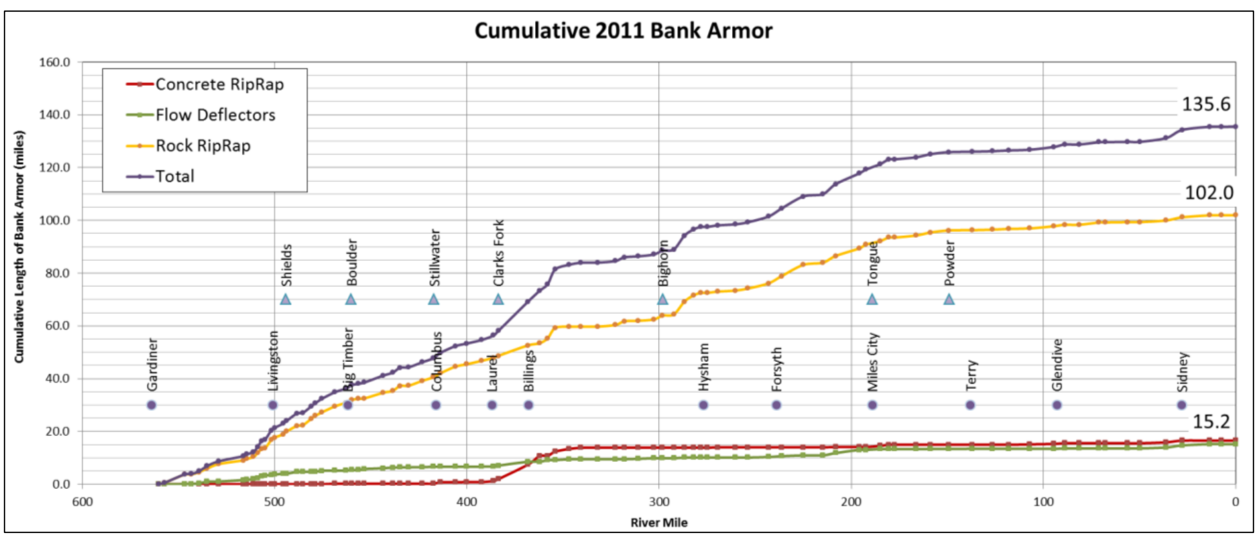


Figure 4-76 Cumulative upstream to downstream plot showing bank armor trends for rock riprap, concrete riprap, and flow deflectors

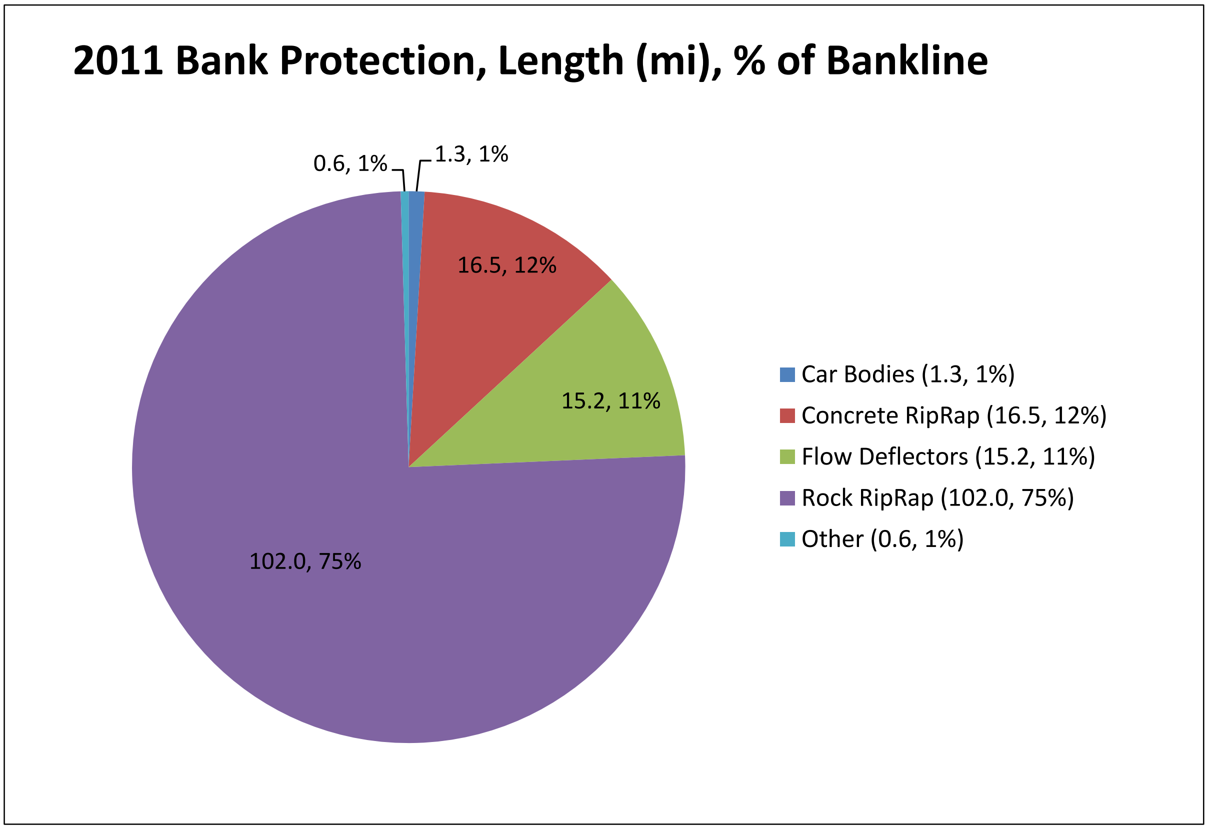


Figure 4-77 Relative extents of bank armor types, 2011

Figure 4-78 Flanked armor in the middle of the river, Region C

The dominant land uses protected by bank armor are agriculture and the active rail line, which collectively account for 73 percent of the total mapped bank protection (Figure 4-79). The third most common application of bank armor is in urban/exurban areas. Most communities on the river are characterized by high concentrations of bank armor; between Laurel and Billings, over 30 percent of the bankline is consistently armored (Figure 4-80).

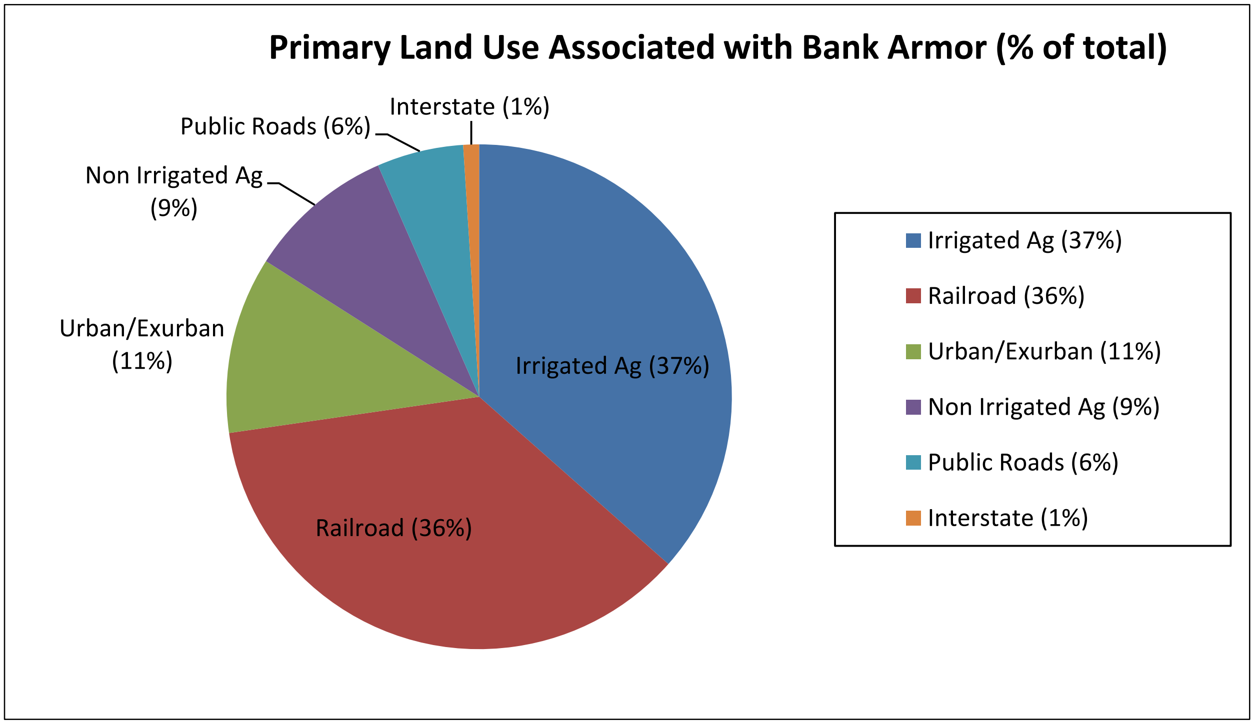


Figure 4-79 Types of land uses protected by bank armor, Regions A-D

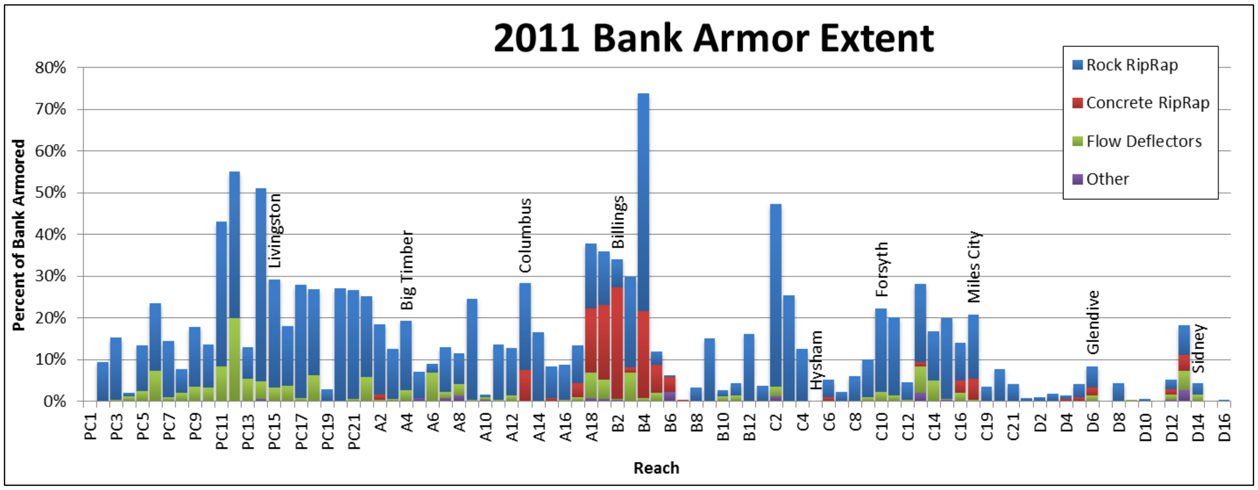


Figure 4-80 Percent of streambanks armored by reach

There is no clear correlation between armor extent and geomorphic process due to the variable impact of armor with regard to the impedance of natural channel movement. The data are clear that the Yellowstone River has experienced reduced rates of movement and floodplain turnover along with ever increasing extents of bank armor. These processes are very likely linked; however, the quantitative correlation of these parameters will require more detailed investigation.

4.5.3.7 Potential Downcutting

There are limited data available to assess the extent of vertical downcutting on the Yellowstone River. However previous studies show some evidence of local downcutting near South Billings Blvd. where bank armor density is high (Reach B1; Womack and Associates 2001). This is supported by observations of secondary channels from 1950 being passively perched in this area by 2001 (Appendix 4 (Geomorphology)). Downcutting can result in a lowering of base level at tributary confluences, which will drive incision on those streams.

4.5.4 Primary Human Influences affecting Yellowstone River Geomorphology

The following section describes the primary potential linkages between human influences and river form and process on the Yellowstone River. The geomorphic changes identified on the river consist of an overall reduction in geomorphic complexity and dampening in rates of change such as channel migration and floodplain turnover. These shifts in river geomorphology are described below with respect to potential drivers and associated interrelationships.

4.5.4.1 Altered Hydrograph

As described in Section 4.2, the hydrology of the Yellowstone River has been substantially altered due to both irrigation practices throughout the basin and dam operations on the Bighorn River. The primary types of flow alterations that have the potential to impact geomorphic parameters include reduction in the duration and magnitude of channel-forming flows and reduced flood magnitudes. Both of these flow regimes impart work in the geomorphic system and their reduction can result in the following:

1. Reduced total bankfull area: If channel forming flow magnitudes and durations are reduced, the channel will respond via riparian encroachment into areas that were previously regularly scoured, and in an eventual contraction of the channel. These reductions in bankfull area that are at least in part related to lower flows on the river are concentrated below the mouth of the Bighorn River, indicating that flow alterations on the Bighorn River are a primary driver of reduced bankfull channel area (Figure 4-70).

2. Abandoned anabranching channels: Lowered flow magnitudes result in sediment infilling and passive abandonment of side channels. This process was identified as a major driver in the abandonment of side channels on the Bighorn River (USBOR 2010). In their study of side channel abandonment on the Bighorn River below Yellowtail Dam, USBOR (2010) concluded that flow reductions resulted in less frequent and lower energy inundation of side channels, which resulted in sediment deposition at the entrances of those channels. Since the channels were dry for longer periods of time, vegetation encroached into the channels, which further inhibited side channel scouring and maintenance.

3. Reduced rates of channel migration, floodplain turnover, and large woody debris recruitment: Reduced instream energy due to lower flows results in lower rates of bank movement and floodplain turnover. This in turn reduces the rate of large woody debris recruitment to the river.

4. Loss of mid-channel bars. Flow alterations that result in riparian encroachment into the stream channel will stabilize historical bar features and reduce the number of open gravel bars in the river footprint.

5. Increased winter-time bank erosion: Increased winter flows due to dam operations have the potential to alter the rates and patterns of wintertime bank erosion. Although this has not been

investigated as part of the Cumulative Effects Investigation, there has been some input from local stakeholders in the Hysham area to that effect.

6. On a more localized level of flow alterations, urban storm water and agricultural runoff that is routed back to the river through ditches or tributaries can result in downcutting and destabilization of those geomorphic features.

4.5.4.2 Land Use Conversion within the Channel Migration Zone

As described in Appendix 4 (Geomorphology), there has been substantial development of land within the Channel Migration Zone (CMZ) of the Yellowstone River. Within the historical migration zone, which defines the collective footprint of the river since 1950, about 830 acres of ground have been converted to irrigated agriculture. At Billings, over 80 acres of the historical migration zone have been developed to urban/exurban land uses. Other map units in the CMZ footprint include the Erosion Hazard Zone, which identifies areas prone to future erosion as the river continues to migrate across its floodplain, and the Avulsion Hazard Zone, which identifies areas prone to excavation of new channels through meander cutoff or floodplain avulsion. Development within the erosion/avulsion hazard zone therefore reflects land use conversions adjacent to the active river corridor where risk of erosion is high. These areas, which in combination with the historical migration zone delineate the active river corridor, have been extensively developed for irrigation, transportation, and urban/exurban land uses. As of 2011, approximately 19,500 acres of land mapped within the erosion/avulsion hazard zone were irrigated, representing about a third of the entire erosion/avulsion hazard zone (Figure 4-81).

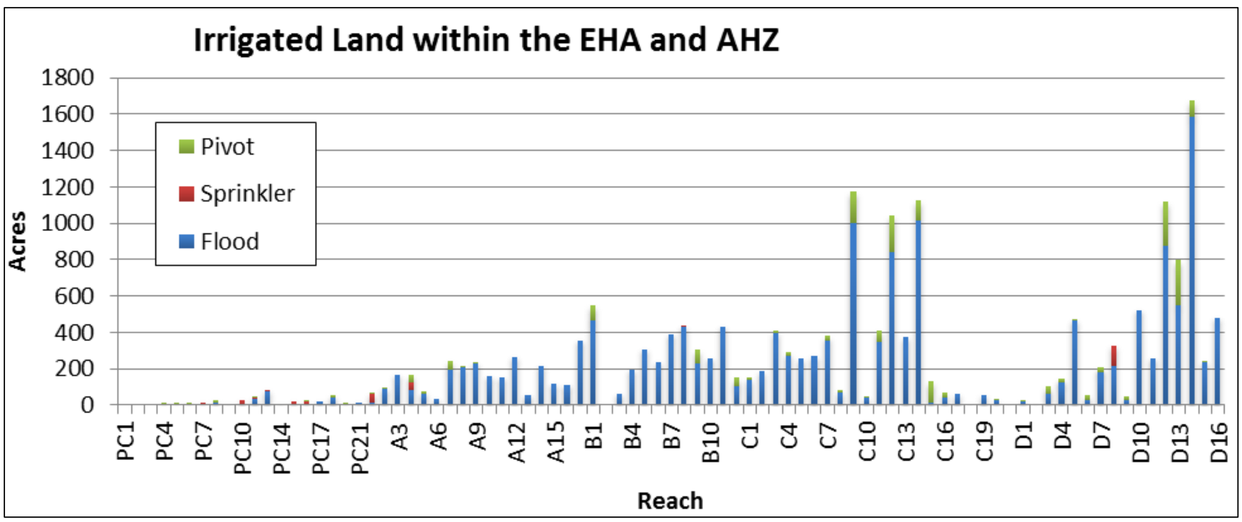


Figure 4-81 Total extent of irrigated land within erosion/avulsion hazard zone by reach, 2011

In 1950, about 1,500 acres of urban, exurban, and transportation–related land was located within the erosion/avulsion hazard zone of the Yellowstone River. By 2011, that number approximately doubled to 3,311 acres (Figure 4-82).

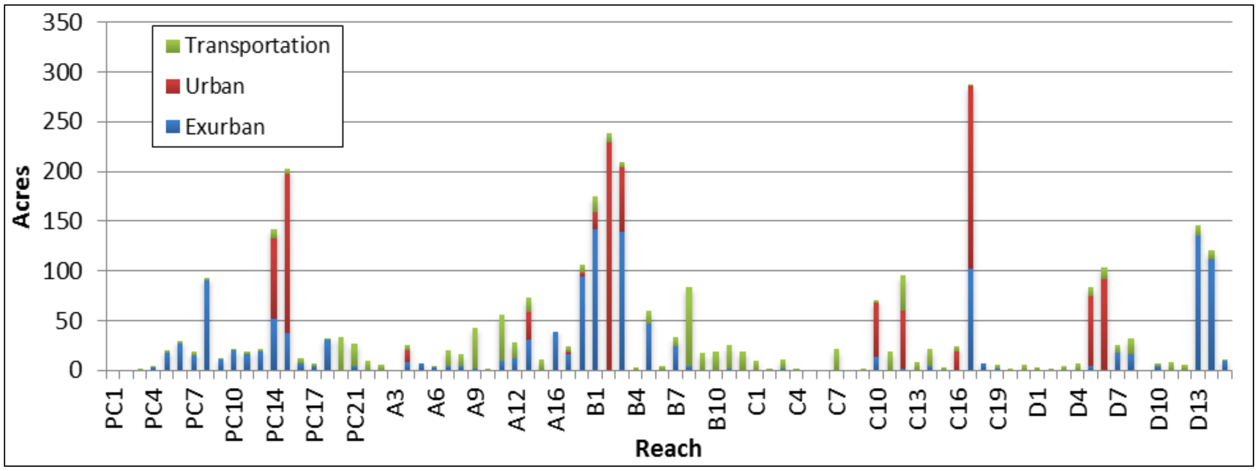


Figure 4-82 Total extent of urban/exurban and transportation land use within erosion/avulsion hazard zone by reach, 2011

The nature and extent of development within the Yellowstone River corridor indicates that infrastructure investment in areas along the river that are prone to erosion has been ongoing since pre-1950 (Appendix 4 (Geomorphology)). With regard to Cumulative Impacts, development within the CMZ commonly consists of the following impacts:

1. Riparian clearing and wetland modifications.
2. Altered channel migration rates: The analysis of migration rates indicates that agricultural areas that have been cleared of riparian vegetation have higher migration rates than areas defined as “multi-use,” which includes riparian bottoms that support woody riparian vegetation, primarily cottonwood forest (Appendix 4 (Geomorphology)).
3. Expansion of bank armor to protect those areas at risk of river erosion (see Figure 4-83).
4. Blockage of side channels to expand developable areas and facilitate access to those areas.
5. Reduced LWD recruitment. Large Woody Debris recruitment is a function of both the rates of floodplain turnover and the availability of riparian forest for recruitment (Figure 4-84). Riparian clearing reduces the overall availability of riparian forest for recruitment.

4.5.4.3 Physical Isolation of Floodplain and Side Channels

Section 4.4.3.2 describes the role of floodplain dikes on isolating floodplain area. In addition to floodplain dikes, small field dikes have been constructed to block side channels since before 1950 (Figure 4-85). These impacts can drive the following geomorphic responses that are seen in the geomorphology data:

1. Active abandonment of side channels due to physical blockages. This impact is clearly demonstrated along the entire length of the Yellowstone River.
2. Potential local downcutting. When side channels are abandoned or the floodplain is constricted, the remaining flow is focused into the main thread, which can cause flow concentration and downcutting. The data regarding downcutting on the river are somewhat speculative, and such processes may warrant further study.

Figure 4-83 Active Bank Erosion, Upper Yellowstone River

Figure 4-84 Large woody debris recruitment, Region C

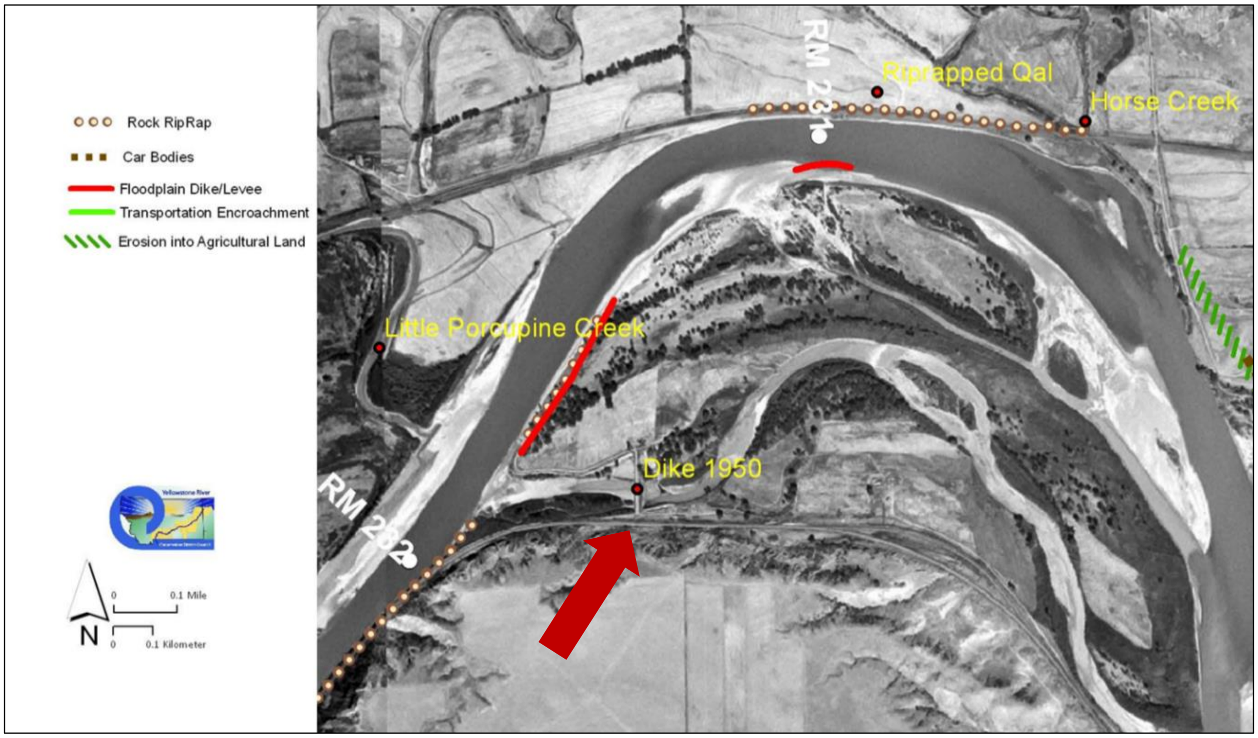


Figure 4-85 Air photo from 1950s of Reach C11 near Cartersville Bridge
Note: *A small dike (red arrow) is blocking a side channel in meander core by 1950; flow is left to right*

4.5.4.4 Bank Armoring

Bank armoring can have both impacts at a local scale as well as on a more regional scale. Bank armor is common on the river in the form of rock riprap, concrete rubble, and flow deflectors (Figure 4-86 and Figure 4-87).

Figure 4-86 Perched flow deflector, Region PC

Figure 4-87 View upstream of rock riprap against agricultural field, Region B

Some of the impacts of bank armoring include the following:

1. Reduced rates of floodplain turnover, channel migration, and LWD recruitment. As bank armor is constructed to stop bank erosion, it directly reduces rates of turnover and recruitment of wood into the river.

2. Channel downcutting. On a larger scale, extensive bank armor can focus flows, and increase velocities at a given discharge. This has been noted as a driver for reach-scale channel downcutting. According to the State of Washington Integrated Streambank Protection Guidelines (Cramer et al. 2002), riprap projects cumulatively tend to lead to channel shortening, incision, and degradation of aquatic and riparian habitat.

3. Reduced mid-channel bar extent. Bank armor reduces rates of sediment recruitment from banklines, which can reduce overall sediment loading to streams. This in turn can result in a loss of mid-channel bars, especially where sediment loading is further reduced by impoundments such as below the mouth of the Bighorn River.

4.5.4.5 Altered Sediment Regime

Bank armoring and sediment trapping in reservoirs both reduce sediment loading to the Yellowstone River. The primary driver for sediment regime alteration on the Yellowstone River is Yellowtail Dam.

Upstream of the mouth of the Bighorn River, there are substantial sediment inputs from both tributaries and streambanks. In the Paradise Valley, for example, there are some very large sediment sources that create very dynamic river channels downstream (Figure 4-88).

Figure 4-88 Natural sediment recruitment from high glacial outwash terraces, Region PC

Further downstream, sediment regime alterations become more prevalent. Prior to the completion of Yellowtail dam, the estimated annual sediment delivery at the mouth of the Bighorn River was estimated at 7.2 million tons/year. Based on 6 years of post-dam data, sediment production was reduced by 80 percent to 1.5 million tons per year (Silverman and Tomlinson 1984). Koch et al. (1977) showed that the spatial extent of gravel bars on the Bighorn River was reduced by 77 percent following dam completion.

In 2010, the Bureau of Reclamation estimated that Bighorn Reservoir was capturing 5.2 million cubic yards (3,224 acre-feet) of sediment per year (USBOR 2010b). The analysis of floodplain turnover rates on the river indicates that since 1976 the mean floodplain turnover rate on the river has dropped by 180 acres per year. Using an estimated 9-foot bank height, this equates to about 2.6 millions of cubic yards of material that is no longer entering the river from streambanks on an annual basis. That coarse estimate indicates that with regard to major causes of sediment reduction, sediment storage at Bighorn Reservoir accounts for about 2/3 of the total reduction of 7.8 million cubic yards per year (Figure 4-89). The storage estimate should also be considered conservative as it does not include sediment stored in Buffalo Bill and Boysen Reservoirs upstream.

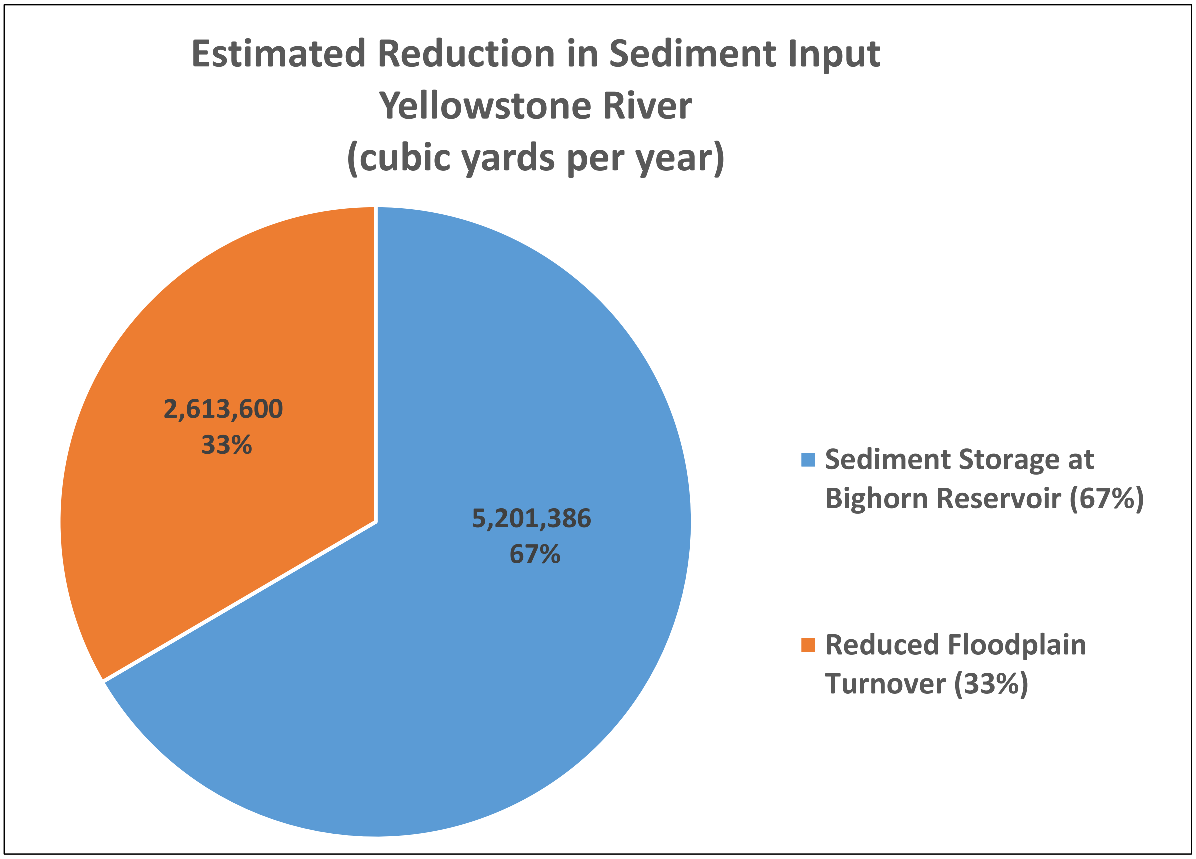


Figure 4-89 Estimated reduction in sediment delivery from Bighorn Reservoir Storage and Mainstem Yellowstone Bank Erosion (reservoir storage volumes from USBOR 2010b)

Impacts associated with a reductin in sediment loading include the following:

1. Channel downcutting: This is a common geomorphic response to reduced sediment loading. On the Bighorn River, however, the USBOR (2010) concluded that there has been no downcutting on that system below the dam. The impacts on the Yellowstone River, which is finer grained and more susceptible to vertical adjustment, are uncertain.

2. Reduced open gravel bars: In combination with flow alterations, sediment loading reductions will result in a reduced extent of dynamic in-stream gravel bars. Commonly, streams that have been starved of sediment result in coarse armoring of their beds, which results in reduced overall rates of gravel bar formation and reworking.

4.5.4.6 Invasive Species

Invasive species have the potential to affect river process. Manners (2013) found that the encroachment of non-native saltcedar into the riparian corridor initiated channel narrowing. Saltcedar infestations altered river processes by promoting floodplain deposition and reducing floodplain stripping (Manners 2013). The tamarisk first stabilized on mid-channel bars, and then established in floodplain depressions, significantly narrowing the river channel. Ongoing saltcedar expansion on the Yellowstone River may contribute to trends of reduced bank migration rates and reduced bankfull channel area.

4.6 Water Quality

4.6.1 Introduction

Water quality is commonly defined as the chemical, physical, biological, and radiological properties of water relative to an intended use such as for drinking water, industry, agriculture, aquatic life support, or recreation. Water quality is an important aspect of any river system, especially so for the Yellowstone River, which originates near Yellowstone National Park and represents one of the few remaining relatively unmodified river ecosystems in the lower 48 states. Human (anthropogenic) and natural factors influence water quality throughout the diverse environmental setting of the 71,000 square mile (nearly 45 million acres) Yellowstone River Basin (Zelt et al. 1999 and North Dakota Department of Health). As the cumulative drain for the basin, the Yellowstone River integrates water quality characteristics of all land uses and human activities in its many tributaries.

Appendix 5 (Water Quality) contains a thorough review and presentation of pertinent Yellowstone River data, specific studies, and peer reviewed literature. For the purpose of the Cumulative Effects Analysis (CEA) report, water quality is presented and evaluated primarily for the mainstem Yellowstone River in Montana and North Dakota, but does address water quality-related issues for major tributaries and the larger Yellowstone drainage basin, as appropriate. Table 4-8 provides a matrix indicating the principle human influences on water quality and the estimated scope and scale of those influences that are addressed in this report.

Table 4-8
Principle Human Influences on Water Quality in the Yellowstone River

Human Influence	Impact on Water Quality	Spatial Extent	Relative Impact on Water Quality
Transportation – roads and bridges	Pollution Runoff: deicer, organic and petroleum compounds, and sediment	System-wide	Slight
	Pollutant Spills: petroleum products and hazardous materials	System-wide at bridge and pipeline crossings	Major
Agriculture - irrigation	Irrigation Return Flow and Leaching: elevated nutrients, salts, pesticides, and sediment	System-wide	Major
	Irrigation Withdrawals: reduced summer low flows: pollutant concentration, water temperature increase and reduced DO	Below Bighorn	Major
Agriculture – Animal Feeding Operations	Runoff and Ground Water Discharge: sediment, nutrients, organic matter, and pathogens	Limited extent system-wide but pronounced in specific reaches	Moderate
Agriculture – Land Use Conversion	Riparian and Wetland Conversion to Ag Cropland: sediment, nutrients, salts, and pesticides	System-wide	Major
Agriculture - Grazing	Riparian and Wetland Alteration: sediment, nutrients, pathogens and invasive species	System-wide	Moderate

Human Influence	Impact on Water Quality	Spatial Extent	Relative Impact on Water Quality
Urban/Exurban – Land Use Conversion	Conversion within 100-year FP to Urban/Exurban: sediment, nutrients, pathogens, semi-volatile organic compounds (SVOCs), and pharmaceuticals	System-wide, but pronounced near larger cities and towns	Major
Urban/Exurban-Urbanization	Stormwater Runoff/Impermeable Surfaces: altered hydrology, elevated water temperature, deicers, sediment, grease, pathogens, nutrients, pesticides, and organic compounds, and SVOCs	Specific Reaches near large urban centers	Moderate
Exurban – pollutant discharge	Septic system ground water pollution: nutrients, pathogens, pharmaceuticals	System-wide, but pronounced near population centers	Moderate
Municipal/Industrial Discharge	Wastewater Discharge: nutrients, pharmaceuticals, metals, SVOCs, and total organic carbon	Specific reaches near large urban centers, primarily in the Park City to Huntley corridor	Major
Municipal/Industrial Water Use	Water Withdrawals: reduced summer low flow: pollutant concentration, water temperature increase, and reduced DO	Below Bighorn	Slight
Off-Channel: Bighorn Reservoir	Hydrologic Alteration: reduced spring high flow; lower summer low flow; higher winter flows; elevated winter water temperatures; and reduced sediment delivery	Below Bighorn	Major
Invasive Species	Altered Riparian and Wetland Communities: nutrients, salt, and altered carbon cycle	System-wide, but primarily Regions B-C	Major
Climate Change	Modified Hydrograph: earlier, runoff; lower late season flow and lower base flow; concentrated pollutants; and warmer water temperatures	System-wide, but accumulative effect downstream	But if recent trends continue, the impact is rated moderate in the short-term and major in the long-term.

4.6.2 Summary of Existing Data

Water quality, bed and suspended sediment, and fish tissue data for the Cumulative Effects Analysis (CEA) reaches has been compiled using a number of data sources and correlated to one of the 11 Montana Department of Environmental Quality (MDEQ) assessment unit identification codes (AUIDs) for the Yellowstone River. Analysis of USGS records at the ten Yellowstone River mainstem gaging stations along with other analytic results downloaded from the Water Quality Portal were used to characterize past and present conditions on the Yellowstone River (MDEQ 2014a; USGS 2014b; and PBS&J 2005). Figure 4-90 shows the relative locations of the USGS gages.

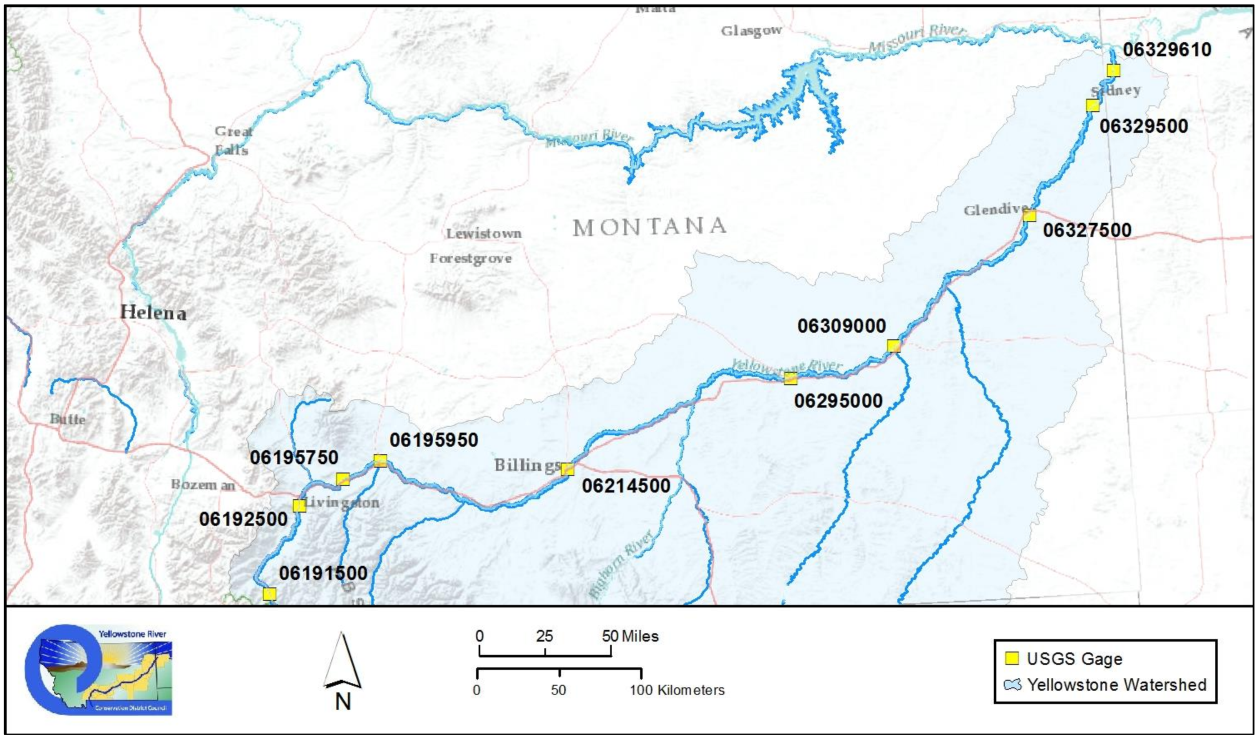


Figure 4-90 Map of Yellowstone River fixed stream gage and water quality stations operated by the USGS

Note: For a list of Montana stream gages operated by the USGS in Montana see http://waterdata.usgs.gov/MT/nwis/current/?type=flow

Table 4-9 provides a general correlation of USGS fixed-station gages with the geomorphic reaches established for the Yellowstone River. Results presented for the respective USGS stations are largely representative of conditions upstream of the station unless noted otherwise. The station at Billings integrates water quality of the Yellowstone River with that of the Clarks Fork, which enters above the station. Similarly, the Forsyth station integrates the Bighorn River and the Glendive station integrates the effect of the Powder River and the Tongue River on the Yellowstone River. Water quality concentrations are presented here in metric units as they are commonly reported throughout the academic and scientific community. Conversions to English units are included, as appropriate.

4.6.3 Water and Sediment Quality

Water quality of the Yellowstone River is sensitive to geographic location since common chemical and physical parameters used to characterize water quality vary considerably as a result of differences in physiographic, climatic, geologic, and anthropomorphic influences within the very diverse region that makes up the Yellowstone River watershed. Following is a discussion of the major water quality and bed sediment characteristics of the Yellowstone River taken from a review of pertinent literature and analytic sample analysis.

Table 4-9
USGS Stations along the Yellowstone River in Montana and North Dakota

USGS Station Identification Number	Station Name	Respective CEA Reach Number
06191500	Yellowstone River at Corwin Springs, MT	PC1 – PC2
06192500	Yellowstone River near Livingston, MT	PC3 – PC14
06195750	Yellowstone River at Springdale, MT	PC15 – PC21
06195950	Yellowstone River at Big Timber, MT	A1 – A4
06214500	Yellowstone River at Billings, MT	A5 – B1
06295000	Yellowstone River at Forsyth, MT	B2 – C10
06309000	Yellowstone River at Miles City, MT	C11 – C16
06327500	Yellowstone River at Glendive, MT	C17 – D5
06329500	Yellowstone River near Sidney, MT	D6 – D12
06329610	Yellowstone River No. 2 near Cartwright, ND	D13 – D16

4.6.3.1 Hydrogen Ion (pH) Concentration

Hydrogen Ion concentration is a measure of acidity and alkalinity in water and is typically reported in pH units. A pH value of 7.0 represents a neutral solution; greater than 7.0 is alkaline and below 7.0 is acidic. In general, water in the Yellowstone River is considered alkaline with pH ranging from 7.4 to 8.6. The 1999–2001 National Water Quality Assessment (NAWQA) program reported a maximum pH value at Forsyth of 8.4 and a low pH of 7.2 at Corwin Springs; pH generally increases in a downstream direction and typically is within established Montana and North Dakota water quality standards for pH (Miller et al. 2005).

4.6.3.2 Dissolved Oxygen

Dissolved oxygen (DO) is a measure of how much oxygen gas is dissolved in water. DO comes from the atmosphere and from photosynthesis by aquatic plants and is depleted through chemical oxidation and respiration by aquatic animals and microorganisms, especially during the decomposition of plant biomass and other organic material. The amount of oxygen that dissolves varies in daily and seasonal patterns, and decreases with higher temperature, salinity, and elevation (atmospheric pressure). Cold water holds twice as much DO as warm water (Wetzel 2001). Water quality standards for DO are based on aquatic life stages present rather than a single concentration (MDEQ 2012a). Concentrations of DO are generally around 8 to 10 mg/L. Several instances of low DO levels below Billings (B3-B4 during summer 2010) may be related to moderate levels of eutrophication noted in following sections of this report. Summer season values are typically higher in the river's headwaters and lower going downstream as water temperature increases (Miller et al. 2005).

4.6.3.3 Total Dissolved Solids

The amount of dissolved material in water is called Total Dissolved Solids (TDS) and is typically expressed in milligrams per liter (mg/L). TDS includes sodium, calcium, magnesium, bicarbonate, chloride, and other water soluble material that remains as a solid residue after the liquid is evaporated. Excess dissolved solids can adversely affect aquatic life, industrial, agricultural, and drinking water beneficial uses. TDS concentration is expressed in units of milligrams per liter (mg/L), but a measurement of electrical conductivity (EC), which is another measurement of dissolved minerals (or salinity), is expressed in units of microsiemens per centimeter (µS/cm)[2]. EC is a measure of the capacity of water to conduct electricity; the more ions in water, the more electricity is conducted. TDS values at USGS gage sites on the Yellowstone River are inversely correlated to discharge as indicated at the Sidney gage (Figure 4-91) and increase in lower flow volumes (become more concentrated). Conductivity (µS/cm) shows a good relationship to discharge and appears to still be within the expected range given the environmental setting. Figure 4-92 shows conductivity at stations along the Yellowstone River.

Concentrations of dissolved solids in the Yellowstone River generally increase in a downstream direction as the increasingly larger watershed concentrates naturally weathered minerals. Median dissolved solids concentrations in the Yellowstone River increased from 152 mg/L near its headwaters to 453 mg/L at the farthest downstream site at Sidney. Human activity that results in increased weathering and delivery of minerals such as irrigation, coal mining, oil extraction, and industrial and municipal wastewater discharges can elevate dissolved solids in the river. EC values below 1,000 µS/cm are considered well suited for most uses, with irrigation generally having the greatest sensitivity since plant functions are affected by higher EC values. Values greater than 2000 µS/cm are considered detrimental for long-term irrigation. Currently, there is insufficient data to know how much TDS or EC concentrations have increased in the Yellowstone River.

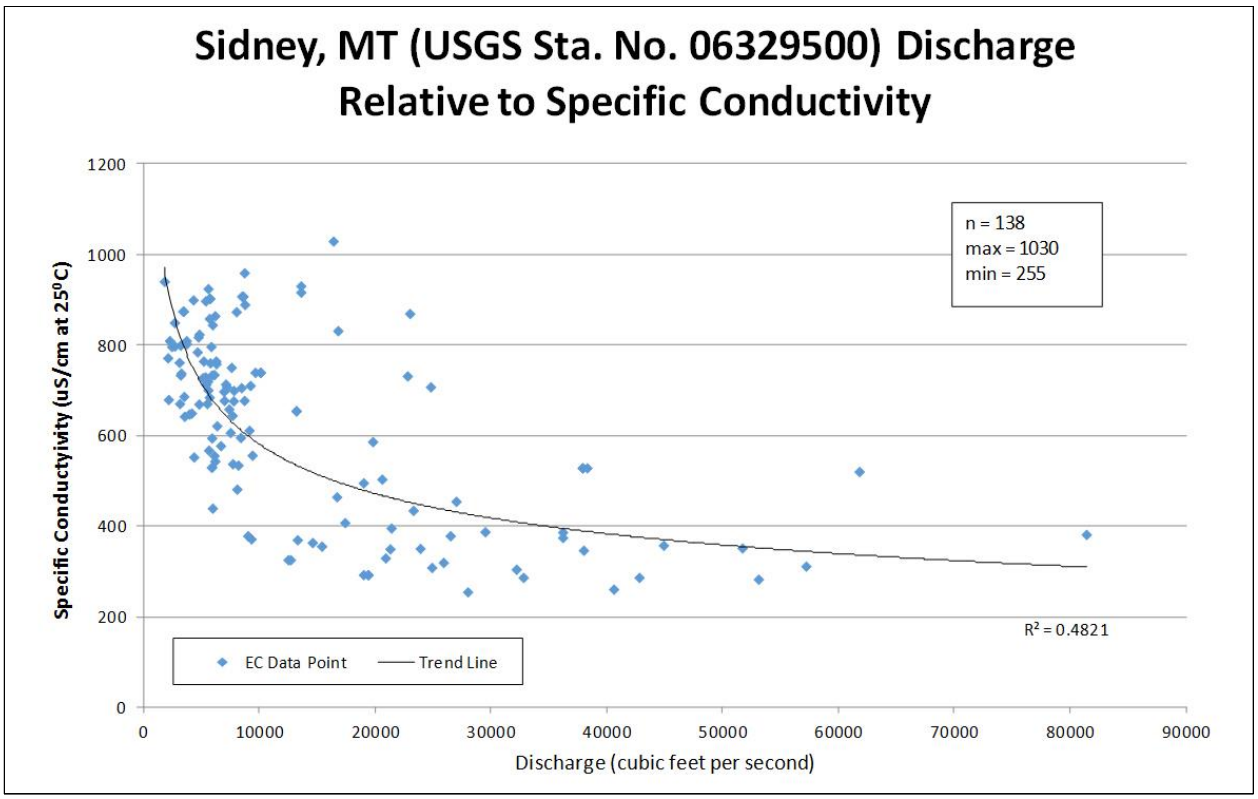


Figure 4-91 Specific conductivity at USGS gage at Sidney
Note: *Gage represents the water quality of the final 75 miles or so of the Yellowstone River water before the confluence with the Missouri*

[2] There is not a standard direct relationship between TDS concentrations in mg/L and EC in µS/cm; however, the relationship generally ranges from 0.5 to 0.7 times µS/cm = mg/L.

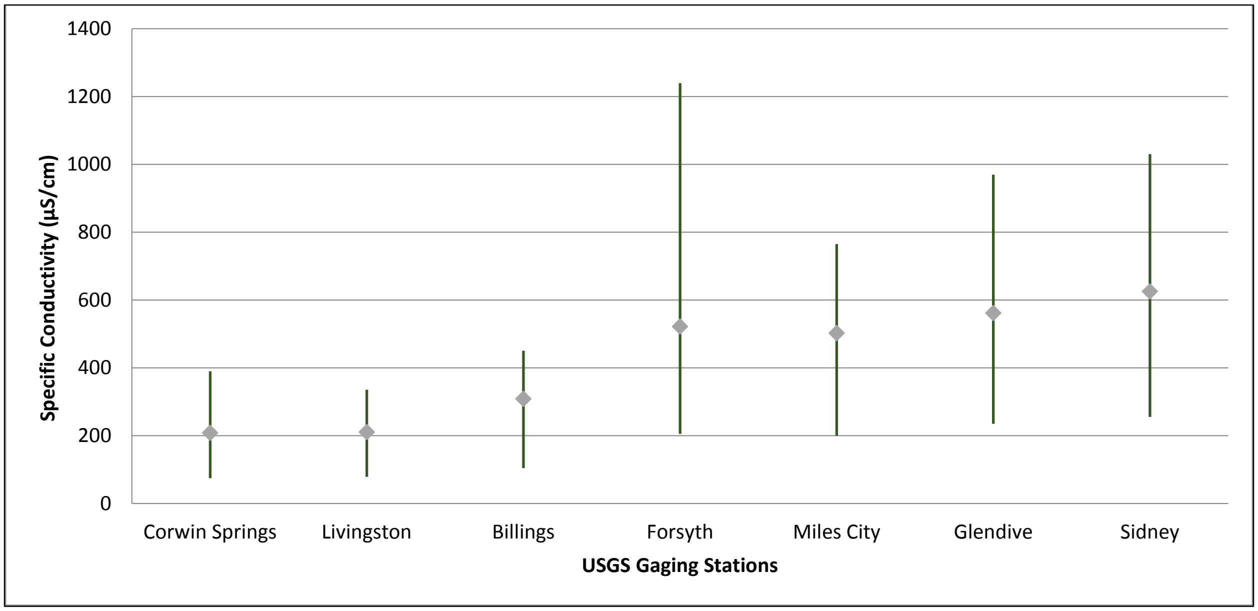


Figure 4-92 Range of values for specific conductivity (µS/cm) at seven fixed-station USGS gages along the Yellowstone River

Note: Values increase going downriver as salts and other dissolved ions accumulate

Neither Montana nor North Dakota has established numeric water quality standards for EC in the Yellowstone River. Montana designated seasonal numeric EC and sodium adsorption ratio (SAR) standards for the Powder River, Little Power River, Tongue River, and Rosebud Creek tributary drainages in conjunction with efforts to protect use of these waters for irrigation and aquatic life (ARM 17.30.670) in light of increased groundwater discharges in Wyoming and Montana as part of expanding coal-bed gas development and production in the late 1990s and early 2000s. Coal-bed gas development involves dewatering coal seams to release trapped methane gas. Pumped coal-bed gas groundwater is typically stored or released to nearby drainages after the gas is trapped and stored. Statistically weak trends in EC and associated SAR values at some sampling sites on the Tongue and Powder Rivers have been noted and possibly attributed to coal-bed gas production and other sources (Sando et al. 2014; Clark 2012).

4.6.3.4 Nutrients

Phosphorus and nitrogen play an important role in the growth of nearly all organisms. However, when they are present in high concentrations, they become pollutants (USEPA 2014a). The primary effect of excessive nutrients in rivers, lakes, and streams is to stimulate algal and aquatic plant growth (see Figure 4-93). Some algal species produce potent toxins that kill humans, livestock, and aquatic and terrestrial wildlife (see Table 4-10). Algal growth can also produce undesirable odors and taste in drinking water. Excess nutrients are responsible for impairment of some 206 assessment units (total N) and 235 assessment units (total P) in streams in Montana (MDEQ 2014).

Nutrient concentrations vary by season. Dissolved nitrate concentrations generally are largest between October and March when plant growth and nutrient uptake is low and ground water influence is greater (Peterson and Porter 2002). Nitrate concentrations in the Yellowstone River increased downstream from an average of about 0.08 mg/L at Corwin Springs to an average of greater than 0.3 mg/L near Sidney (Miller et al. 2005; Peterson et al. 2004). Nitrate-nitrogen concentrations generally remained below detection limits, though a value of 0.053 mg/L was recorded at Billings and a value of 0.772 mg/L was recorded in the Clarks Fork of the Yellowstone River.

Figure 4-93 Excessive benthic algal growth is shown in this photo of streambed cobble

Table 4-10
Impacts of Excessive Algal Growth on Water Bodies

Impacts to Human Uses	Impacts to Aquatic Uses
Drinking water taste and odor	Harmful diel (night/day) fluctuations in pH and DO
Water clarity is reduced	Total biomass of algae is increased relative to other organisms
Blockage of intake screens and filters	Changes in species composition of algae and related diatoms
Disruption of water treatment processes	Macrophyte over-abundance – impedes flow and passage
Increased disinfection required which creates potential carcinogens in drinking water	Reduces macroinvertebrate and fish habitat especially near shorelines
Swimming, boating, and other recreational uses are restricted	Increased probability of fish kills due to depleted dissolved oxygen
Fouling of submerged infrastructure	Toxin producing algae (more so in reservoirs)
Reduced property values and amenity (odor and aesthetics)	Affects distribution and abundance of fishery
Lost tourism income	
Source: Smith et al. (1997) and Dodds et al. (2009) cited in Flynn and Suplee (2013).	

Tributaries are a sizeable source of nutrient load in the Yellowstone River. Instantaneous dissolved nitrate loads of 280 kilograms per day (kg/d) and 297 kg/d were estimated for the Yellowstone River at Billings and the Clarks Fork, respectively, while the Bighorn River had an instantaneous dissolved nitrate load of 775 kg/d. Dissolved nitrate concentrations are higher in basins with more agricultural and grazing lands compared to forest lands. Corwin Springs, Montana, had the greatest ammonia concentrations and is influenced by geothermal spring waters that are high in ammonia.

Total phosphorus concentrations increased from 0.016 mg/L at Corwin Springs to 0.038 mg/L in the lower segments of the river. Total phosphorus concentrations are largest between April and June when suspended sediment in runoff is at its peak concentration (Miller et al. 2005).

Total nitrogen and phosphorus values during the growing season are generally within the numeric nitrogen and phosphorus standards proposed by the MDEQ (Flynn and Suplee 2013; Suplee et al. 2014). The proposed standards are 55 micrograms per liter (µg/L) total phosphorus and 655 µg/L total nitrogen between the Bighorn and Powder Rivers and 95 µg/L total phosphorus and 815 µg/L total nitrogen from the Powder River confluence to the Montana state line. The numeric standards were developed to protect recreational uses. The standard for benthic algal density (Chlorophyll *a*) is less than 150 milligrams per square meter (mg/m^2) during the growing season (Suplee et al. 2014). Winter total phosphorus and total nitrogen concentrations occasionally exceed the standard. Development of numeric nutrient criteria for upper sections of the river is in progress.

Although concentrations of nutrients in the Yellowstone River have been found to occur at relatively low values, nutrient enrichment in Regions PC, A, B, and C and major tributaries (Clarks Fork, Bighorn and Powder Rivers) has been identified (Peterson and Porter 2002; Peterson et al. 2004). Nuisance growth of filamentous algae occurs in segments of the Bighorn River and Clarks Fork (Peterson and Porter 2002). Microalgae biomass was greatest near Billings (Reach B2) and Forsyth (Reach C10) in the Yellowstone and near the mouths of the major tributaries. Algal standing crops and chlorophyll *a* concentrations were highest in the middle sections of the Yellowstone River and appeared to be related to inflows from the Clarks Fork and Bighorn River. A maximum chlorophyll *a* concentration of 797 mg/m^2 was recorded in the Yellowstone River at Billings (Reach B2). Turbidity in the lower river associated with suspended matter that suppresses available light in the lower river below Forsyth likely plays a role in suppressing algal production there.

Potential sources of nutrients that could drive the observed response of algal biomass in the middle Yellowstone River are atmospheric deposition, upstream residential development (lawn fertilizer, septic tanks, and domestic animal waste), and irrigated agriculture (Flynn and Suplee 2013; Peterson and Porter 2002; Zelt et al. 1999). In the Yellowstone River Basin, nonagricultural sources of phosphorus have contributed an estimated 65 percent of the total phosphorus yield (Smith et al. 1997). Related nutrient enrichment responses in western streams have been associated with increases in rural and residential development in the west. Point sources in the Laurel to Billings reaches (B1 and B2) have been calculated to contribute less than 30 percent of the nitrate load compared to nonpoint source loads contributed by the Clarks Fork (Newby, cited in Peterson and Porter 2002).

Algal biomass and community structure appear to be influenced by the relative availability of nutrients (dissolved inorganic and organic nitrogen) as well as the relative turbidity of the water. For the most part, primary production in the Yellowstone River is considered nitrogen limited. With relatively large amounts of phosphorus available in the Yellowstone River, attention should be given to ensure that sources of additional nitrogen do not increase the moderate levels of eutrophication already observed in the river.

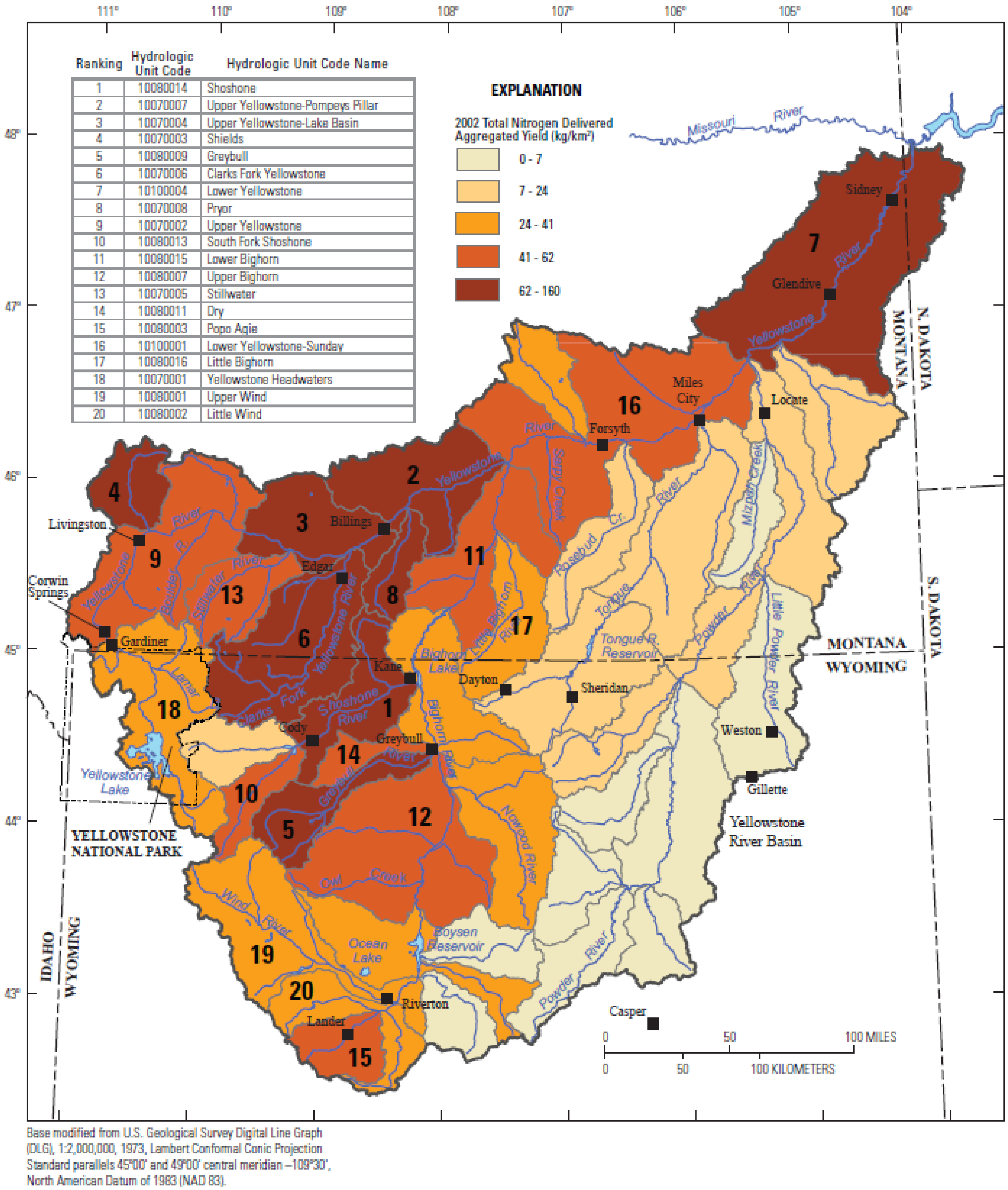
The relative impacts of nutrient export from the Yellowstone River drainage basin into the larger Mississippi River basin were also evaluated (USEPA 2014; Brown et al. 2011 and USEPA 2004a). Results of the Spatially Referenced Regressions On Watershed attributes (SPARROW) model for the Yellowstone River indicate that the estimated delivered aggregated yield of total nitrogen to the Gulf of Mexico is only about 12 kg/km^2/year (0.11 lbs/acre/year) compared to other Mississippi River tributaries that contribute up to an estimated 1,318 kg/km^2/year (11.8 lbs/acre/year) (Frankforter et al. 2015, in review; Brown et al. 2011) (Robertson et al. 2014). Frankforter et al. (2015, in review) used a 2002 base year, Yellowstone specific SPARROW model to rank the top 20 relative sources of total nitrogen using 8-digit Hydrologic Units (HUC8s). The SPARROW model identified six potential sources of total nitrogen: farm fertilizer, manure from confined animals, inputs associated with legume crops, atmospheric deposition, wastewater treatment plants (WWTPs), and urban areas. Seven sources of total phosphorus were identified: farm fertilizers, total manure, WWTPs, urban areas, wetland/forested areas, channels in moderate-size streams, and deeply weathered loess (wind deposited) soils.

The model predicts that the largest source of total nitrogen delivered aggregated yield in the Yellowstone River basin is the Shoshone River basin in Wyoming, followed by the Upper Yellowstone – Pompeys Pillar and the Upper Yellowstone – Lake Basin HUC8s. The top 20 HUC8s are projected to contribute 83 percent of the total nitrogen yield in the basin. Farm fertilizers (41 percent) and atmospheric deposition (30 percent) were the primary sources of delivered nitrogen. Waste water treatment plants were projected to contribute up to 38 percent of the total nitrogen yield in the Upper Yellowstone – Pompeys Pillar HUC8, although it should be noted that potential changes in nitrogen removal technology post-2002 have not been incorporated in the model results.

The SPARROW estimate of the delivered aggregated yield of total phosphorus to the Gulf is 2.73 kg/km^2/year (0.024 lbs/acre/year) as opposed to other drainages contributing as much as 187 kg/km^2/year (1.66 lbs./acre/year) (Frankforter et al. 2015, in review; Robertson and Saad 2013; Brown et al. 2011). The model predicted that the Lower Bighorn watershed and the Upper Yellowstone – Pompeys Pillar and Little Bighorn watersheds were the greatest contributors of delivered aggregated total phosphorus yield. The largest predicted sources of total phosphorus yield came from a variety of sources: natural (stream channel (39 percent), livestock manure (22 percent) (confined and unconfined), and forest and wetland origins (17 percent).

The top 20 HUC8s were ranked to indicate those yielding the greatest total phosphorus yield. The top 20 HUC8s are projected to cumulatively contribute 72 percent of the delivered aggregated yield of total phosphorus in the basin. The relative model-derived contributions and sources of total phosphorus delivered aggregated yield are presented in Figure 4-94 through Figure 4-97.

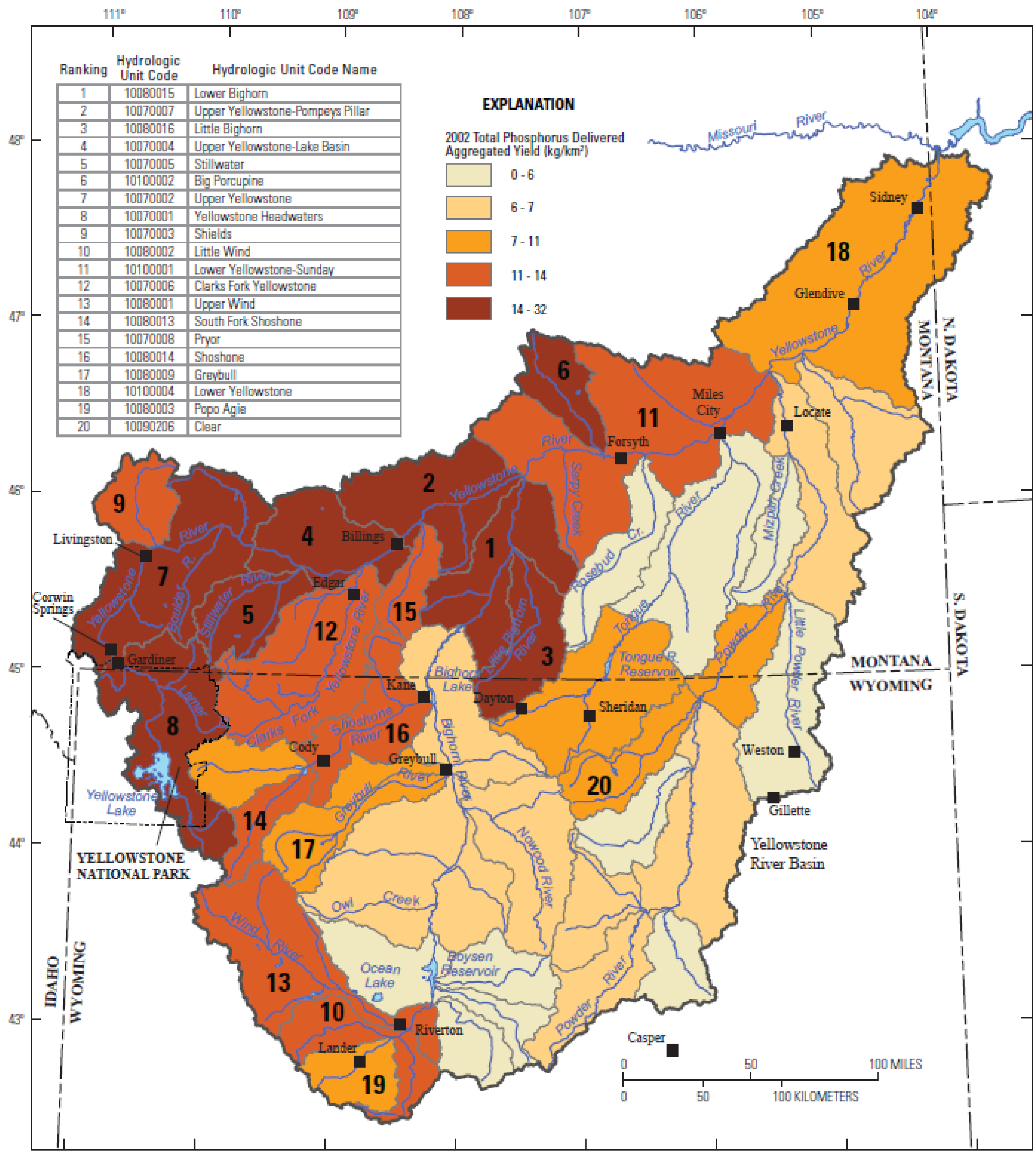
Efforts to reduce nutrient loads and yields in the Yellowstone River should focus on those watersheds contributing the greatest human-related sources of nutrients. Since many of the larger sources and accumulated yields occur on the mainstem and major tributaries, nutrient management efforts will need to utilize a comprehensive watershed approach to have any measurable level of success.



Ranking	Hydrologic Unit Code	Hydrologic Unit Code Name
1	10080014	Shoshone
2	10070007	Upper Yellowstone-Pompeys Pillar
3	10070004	Upper Yellowstone-Lake Basin
4	10070003	Shields
5	10080009	Greybull
6	10070006	Clarks Fork Yellowstone
7	10100004	Lower Yellowstone
8	10070008	Pryor
9	10070002	Upper Yellowstone
10	10080013	South Fork Shoshone
11	10080015	Lower Bighorn
12	10080007	Upper Bighorn
13	10070005	Stillwater
14	10080011	Dry
15	10080003	Popo Agie
16	10100001	Lower Yellowstone-Sunday
17	10080016	Little Bighorn
18	10070001	Yellowstone Headwaters
19	10080001	Upper Wind
20	10080002	Little Wind

Figure 4-94 20 watersheds with highest predicted delivered aggregated yield of total nitrogen within the Yellowstone River Basin in Montana, Wyoming, and North Dakota

Note: As defined by 8-digit hydrologic unit code; values in kilograms per square kilometer per year



Ranking	Hydrologic Unit Code	Hydrologic Unit Code Name
1	10080015	Lower Bighorn
2	10070007	Upper Yellowstone-Pompeys Pillar
3	10080016	Little Bighorn
4	10070004	Upper Yellowstone-Lake Basin
5	10070005	Stillwater
6	10100002	Big Porcupine
7	10070002	Upper Yellowstone
8	10070001	Yellowstone Headwaters
9	10070003	Shields
10	10080002	Little Wind
11	10100001	Lower Yellowstone-Sunday
12	10070006	Clarks Fork Yellowstone
13	10080001	Upper Wind
14	10080013	South Fork Shoshone
15	10070008	Pryor
16	10080014	Shoshone
17	10080009	Greybull
18	10100004	Lower Yellowstone
19	10080003	Popo Agie
20	10090206	Clear

Base modified from U.S. Geological Survey Digital Line Graph (DLG), 1:2,000,000, 1973, Lambert Conformal Conic Projection Standard parallels 45°00' and 49°00' central meridian –109°30', North American Datum of 1983 (NAD 83).

Figure 4-95 20 watersheds with highest predicted delivered aggregated yield of total phosphorus within the Yellowstone River Basin in Montana, Wyoming, and North Dakota

Note: As defined by 8-digit hydrologic unit code; values in kilograms per square kilometer per year

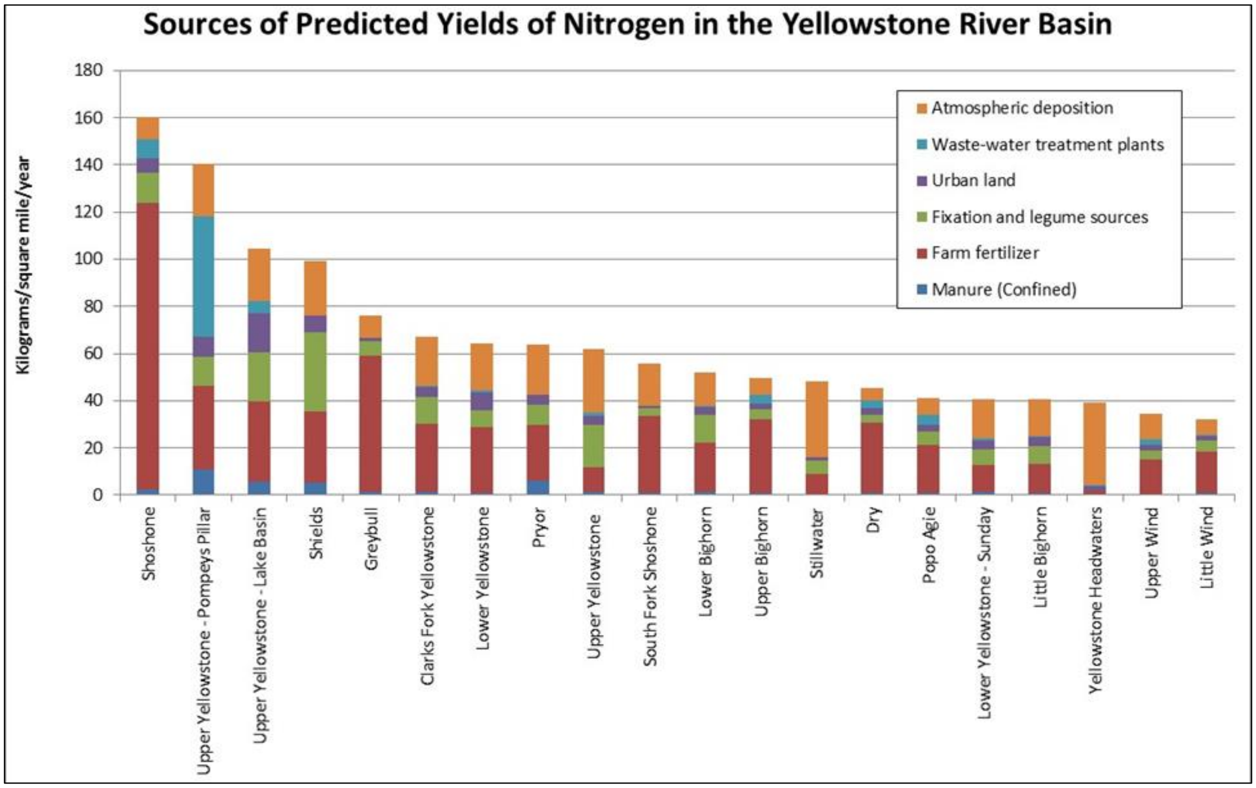


Figure 4-96 **Sources of predicted yields of delivered aggregated nitrogen yields by hydrologic units within the Yellowstone River Basin**

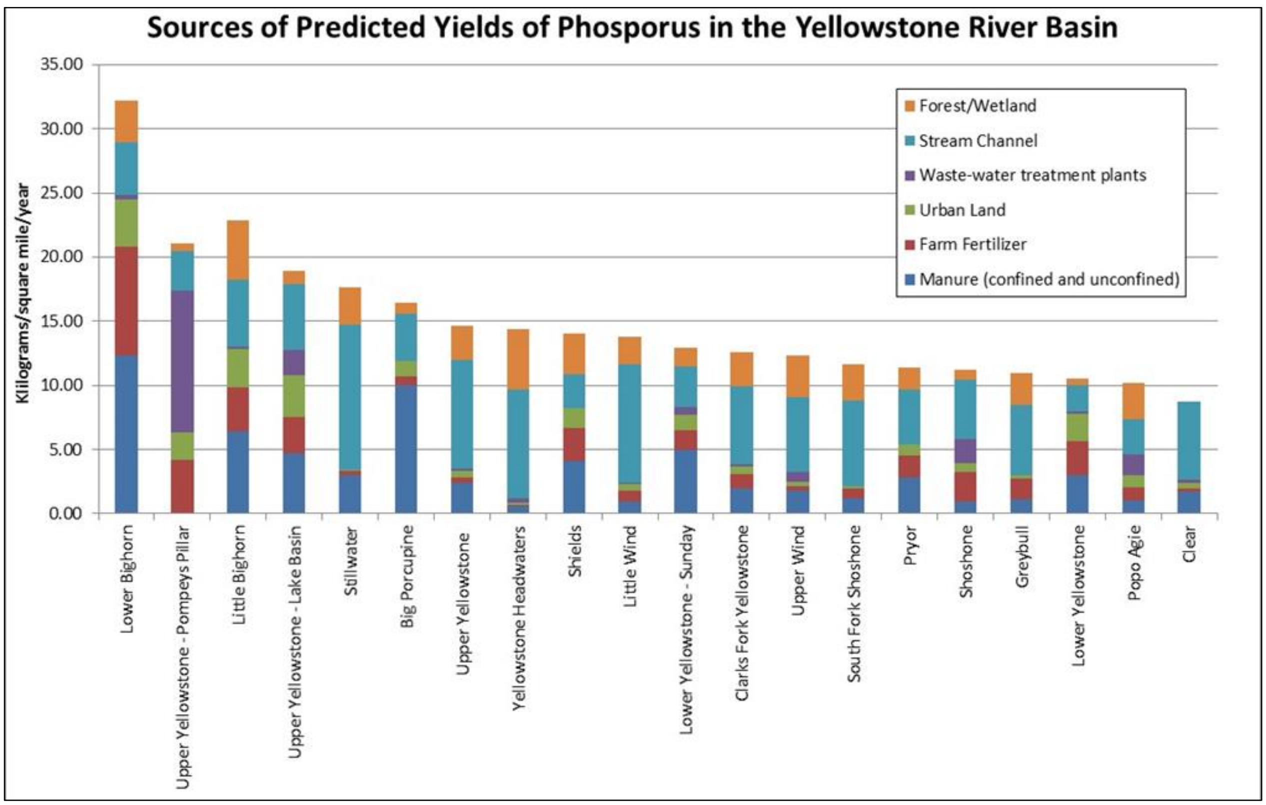


Figure 4-97 **Sources of the predicted yields of delivered aggregated phosphorus yields by hydrologic units within the Yellowstone River Basin**

Frankforter et al. (2015, in review) used the Yellowstone SPARROW Decision Support tool (http://www.cid.USGS.gov/sparrow) to evaluate a number of nutrient management alternatives. The alternatives are discussed and presented in detail in the Water Quality Technical Appendix. In summary, alternatives to reduce nitrogen and phosphorus inputs produced variable results, with the most viable strategies being applied to WWTPs and fertilizer delivery in predominately agricultural watersheds on the mainstem and major tributaries. Projected changes in population in the Yellowstone basin may result in moderate (up to 6 percent) increases in nutrients in specific HUC8s without commensurate upgrades in treatment technology. Major population increases have occurred in the Upper Yellowstone-Pompeys Pillar HUC8 which encompasses the communities of Laurel and Billings, Montana. WWTP treatment upgrades may result in nutrient yield reductions ranging from one to 11 percent.

As noted earlier, one of the major sources of the SPARROW model-projected total phosphorus yield is from in-channel sources due to sediment associated with bank and bed erosion. One scenario evaluated the impact in reduction of this source (Frankforter et al. 2015, in review). The major reductions were predicted in tributaries such as the North Fork Shoshone (11 percent), Middle Powder (13 percent) and the Lower Tongue (17 percent); however it is unlikely this goal could be attained except through targeted improvements to riparian and wetland bank vegetation to reduce the rate of channel erosion. Efforts to reduce channel erosion, except where accelerated due to modifications in bank vegetation, land use, or hydrology, are not recommended and may produce unintended, undesirable results.

4.6.3.5 Trace Elements

Concentrations of trace elements in water samples generally are within recommended levels in the Yellowstone River Basin with a few exceptions. On the Yellowstone River, median concentrations of dissolved arsenic of 21 micrograms per liter (µg/L) at Corwin Springs and 10.5 µg/L at Billings exceed the drinking-water Maximum Contaminant Level (MCL) of 10 µg/L (MDEQ 2012a). For comparison, the median concentration of arsenic at Sidney was 3.25 µg/L in 2014. Seventy-eight percent of samples at Corwin Springs and 60 percent at Billings were above the drinking water MCL. Ingestion of elevated arsenic has been shown to cause skin and circulatory illnesses and is linked to an increased risk of cancer. Geothermal waters from Yellowstone National Park are a significant source of arsenic in the Yellowstone River (Miller et al. 2005).

Selenium is another potentially toxic trace element that is often found in waters draining Cretaceous sedimentary rock (Zelt et al. 1999). Selenium is often mobilized by irrigation of alkaline soils and has been linked to a number of reproductive disorders. Selenium concentrations were low in the Yellowstone River water samples; however, the Powder River samples had concentrations near the Montana aquatic life chronic criterion of 5 µg/L. Selenium can be bioaccumulated in the food chain in predatory organisms.

Peterson and Boughton (2000), following Peterson and Zelt (1999), report that during July to September 1998, 44 trace elements were analyzed in streambed sediment at 24 sites throughout the Yellowstone River Basin. Median concentrations of chromium, copper, and lead were highest at the sites located in Tertiary and Cretaceous volcanic rocks. Median values for copper, arsenic, and lead were significantly less than similar values reported for the South Platte River basin and the Upper Colorado River basin. Values reported in this study are shown in Table 4-11. The Yellowstone River analytic results were within the range of historical observations (1974-1979) reported for the respective geologic time periods within the region. Since there are no established criteria for trace elements in sediment in Montana or North Dakota, guidelines developed by the Canadian Council of Ministers of the Environment (2000) are used as a reference. Concentrations above the probable effect level are expected to be frequently associated with adverse biological effects on aquatic life

Table 4-11
Trace Element Concentrations in Bed-Sediment Samples at Sites on the Yellowstone River, 1998

Site Name	Arsenic	Chromium	Copper	Lead
Corwin Springs	**41**	**180**	**39**	21
Billings	15	**100**	36	29
Forsyth	11	**93**	23	18
Sidney	8.8	**74**	20	17

Source: Peterson and Boughton 2000.

Notes: Bold face numbers designate sediment samples in which a trace element exceeded the respective probable effect level. Values are in micrograms per gram (µg/g) dry weight.

The Yellowstone River NAWQA program collected fish tissue and bed sediment samples in 1998 at Sidney for the purpose of mercury analysis. As reported by Miller et al. (2005) the sauger collected at Sidney contained 1.29 µg/g dry weight mercury, which is about one third the concentration of mercury in samples taken in the Bighorn River, Bighorn Lake, or the Shoshone River. The Sidney concentration is similar to the median and mean concentrations of mercury in a national study of chemical residues in fish tissue (U.S. EPA 1992 cited in Miller et al. 2005). Methyl-mercury, the most toxic form of mercury, was not detectable in the Sidney sediment sample. A three-year study is underway to determine the source of elevated levels of mercury in fish tissue in Bighorn Lake where concentrations were the third-highest measured in 520 fish sampled nationwide (French 2014a). The Montana Department of Fish, Wildlife & Parks (MFWP) has issued mercury-related fish consumption advisories for multiple species in Tongue River Reservoir, Bighorn Lake, and Cooney Reservoir, and for channel catfish in the Yellowstone River near the Powder River confluence (MFWP 2014). Nonpoint and atmospheric sources are thought to be the greatest source of mercury in Tongue River Reservoir (Phillips et al. 1987 cited in Miller et al. 2005), which are likely representative of mercury transport and residence in the basin.

Concentrations of cadmium, chromium, manganese, molybdenum, and vanadium were elevated in fish tissue taken from headwaters drainages associated with natural mineralization and past mining (West Fork Mill Creek and Soda Butte Creek), but no issues were noted for fish tissue at the five Yellowstone River mainstem sites. No Yellowstone River fish tissue samples exceeded selenium threshold concentrations associated with injurious effects to aquatic life (Peterson and Boughton 2000).

4.6.3.6 Pesticides

The Yellowstone NAWQA program investigated and evaluated the occurrence of man-made organic pesticides in the basin during January 1999 to September 2001 and more recently in 2014 (USGS 2014a). Peterson et al. (2004) found that at least one pesticide compound was detected in 87 percent of 136 surface water samples collected at four sites on the Yellowstone River (Corwin Springs, Billings, Forsyth, and Sidney) and two sites on the Clarks Fork and Bighorn Rivers. Pesticides were detected in 54 percent of samples at Billings compared to 95 percent of samples at Sidney. Billings had the least number of pesticides detected (7) while Sidney had the greatest (16) number detected. Pesticide concentrations generally were small in samples for the other three Yellowstone River sites. Compared to other sites around the United States, the Yellowstone samples were in the lowest 25 percent of concentrations measured. Herbicides were more frequently detected than insecticides.

Atrazine was the most commonly detected herbicide and was detected in about 75 percent of the samples. Atrazine was also the pesticide with the greatest observed concentration. Concentrations of all compounds generally were substantially smaller than aquatic-life or human health criteria (for compounds with criteria established). Highly mobile pesticides were detected more frequently and in higher concentrations than less mobile pesticides. Pesticide concentrations were found in higher concentrations after runoff events; however some highly mobile pesticides such as atrazine were found in winter indicating that ground water was likely a means of transport in addition to surface runoff.

DDT was detected in fish tissue at the four mainstem sites on the Yellowstone River (Peterson and Boughton 2000). Sites on the Bighorn River and the Clarks Fork tested positive for multiple organic compounds. The fact that DDT was also detected at the highest levels in cutthroat trout from Yellowstone Lake confirms that the source of the DDT is likely the spruce budworm spraying conducted in the upper watershed in 1957. Peterson and Boughton (2000) report that DDT levels have declined in fish tissue samples over the years since spraying took place.

Possible human health and aquatic life impacts associated with pesticides are related to the limited information available concerning the combined effect of multiple pesticides, even at very small concentrations in the environment, and the fact that many pesticides in use do not have established human health and aquatic life criteria.

4.6.3.7 Hydrocarbons

A number of semi-volatile organic compounds (SVOC) were detected in bed sediment at Yellowstone River sites during the 1998 NAWQA study of Yellowstone River Basin bed sediment (Peterson and Boughton 2000). About 20 of the SVOCs described in the 2000 USGS report are known as polynuclear aromatic hydrocarbons or polycyclic aromatic hydrocarbons (PAHs). Samples from Billings had about 13 PAH compounds found above the detection limit and were the maximum values for the compounds detected in the Yellowstone River Basin. The upper values probably reflect the urban/industrial nature of the Billings location. SVOCs are manufactured chemicals used in fuels, lubricants, solvents, and pesticides. Common sources of PAHs in aquatic systems are atmospheric deposition, municipal and industrial discharges, and urban runoff. Concentrations of PAHs in Corwin Springs, Forsyth, and Sidney sediment samples were very low. Importantly, the concentrations of PAHs in the Billings samples were less than established criteria for protection of aquatic life.

A number of SVOCs known as cresols, phenols, and phthalates were detected in Yellowstone River sediment samples. The Corwin Springs (Reach PC 3) and Billings (Reach B2) samples contained six compounds, with Billings at slightly higher concentrations. Forsyth and Sidney both had three compounds detected with concentrations similar to Billings.

The results indicate that the concentrations of SVOCs for the Yellowstone mainstem sites were below the normal method reporting limit (Peterson and Boughton 2000). Common sources of these compounds are combustion motor exhaust, petroleum refining (gasoline), and other manufacturing, although minute amounts can be due to natural sources (Howard 1989 cited in Peterson and Boughton 2000). Maximum concentrations of several of these SVOC compounds were found in the Little Bighorn River system at the state line.

Crude oil pipeline breaks in 2011 near Laurel and 2015 near Glendive resulted in the release of hydrocarbons directly into the Yellowstone River. Water sampling in both cases did not show toxic levels of hydrocarbons in the river water, although in the case of Glendive, the town's water supply system was shut down for several days. Additional information about the pipeline breaks is discussed in Section 4.6.7.2.

4.6.4 Physical Properties

4.6.4.1 Water Chemistry and Bed Sediment—AUID and Reach Summary

A detailed summary of water chemistry and bed sediment characteristics for the 12 Yellowstone River AUIDs and their equivalent 88 CEA reaches is presented in Table 1.5 in Appendix 5 (Water Quality).

4.6.4.2 Water Temperature

Montana and North Dakota have established water temperature criteria and standards addressing water quality to support aquatic life uses of water. Water temperature standards are based on the relative water-use classification of the Yellowstone River segment (17.30.611 MCA), which specifies the rate and extent of allowable water temperature change. DO, required by aquatic organisms, decreases as water temperature increases. Water temperature also affects the rate of chemical reactions, cues many aquatic life cycle processes, and influences aquatic species composition and distribution (USGS 2015).

Based on the limited data available, some sites show a recent uptick in summer water temperatures; however, this could be related to drought or short-term weather events. Mean warm season (June–September) water temperatures range from 14.75°C (59°F) at Corwin Springs to 20.96°C (70°F) at Sidney, which are within expected values.

Human activities such as discharge of treated wastewater (municipal or industrial effluent), agricultural runoff, forest harvesting (due to effects on shading), urban development that alters the characteristics and rate of stormwater runoff, and climate change (see Section 4.9) might also affect water temperature (MDEQ 2012b). Some pollutants also alter the physical characteristics of water to the point at which more of the sun’s energy is absorbed to raise water temperature. Suspended sediment and algal growth are two examples. Increased water temperature can kill or stress aquatic organisms, making them more susceptible to other sources of disease or death. Montana Fish, Wildlife & Parks divides the Yellowstone River in Montana into three segments based in part on water temperature: the upper coldwater section about 200 miles in length, a transitional cool-warm-water middle section about 90 miles long, and the lower 300-mile long warmwater section (MFWP 2015). More information on impacts of temperature on aquatic organisms is presented in Section 4.9 Aquatic Animals (Fisheries).

During several warm, low-flow summers (2007 and 2012), Montana Fish, Wildlife & Parks and Yellowstone National Park restricted fishing in reaches of the upper Yellowstone River (PC17 thru A12 and the mainstem and tributaries of the Yellowstone and Madison River in Yellowstone National Park) due to elevated water temperature (Skaar 2015; Arnold 2015). Anecdotal reports of water temperature-related fish kills in the upper Yellowstone (Endicott, MFWP personal communication on January 7, 2015) and warmwater species moving further upstream (Opitz, MFWP personal communication on January 7, 2015) as well as a confirmed trend in earlier snowmelt and spring runoff at Livingston (Section 4.3 Hydrology) indicate a need for further study of water temperature in the Yellowstone River to help document trends and identify possible practices to remediate outside influences.

4.6.4.3 Suspended Sediment

Suspended sediment is typically fine silts and clays that are suspended, but not dissolved, within the water column. Natural runoff from rain events, bank erosion, and channel migration can cause the suspension of sediments; excess siltation, however, is a leading cause of water quality impairment in the U.S. and Montana, particularly in lakes where sediment deposition reduces water storage capacity and adds to eutrophication issues (MDEQ 2012b, 2014a). Excessive suspended sediment can alter water quality and aquatic habitat, and affect aquatic organism health. Suspended sediment delivers other water quality pollutants, including nutrients, bacteria, pesticides, and trace elements. High levels of suspended sediment also add to the costs of drinking water treatment. Reporting values are commonly expressed as concentration (mg/L), load (weight/unit of time), and yield (Miller et al. 2005; MDEQ 2012b). Yield is the load per unit watershed area (square miles or square kilometers) upstream from the measuring site.

The highest concentrations of suspended solids in prairie streams typically occur during periods of runoff. Peak runoff in the Yellowstone River occurs in June (USGS 2014b). Suspended sediment concentrations in the Yellowstone River are generally lower in the upper watershed, which drains mountainous terrain, and increase going downriver, where the river passes through and its tributaries drain the softer and more erosive sedimentary plains composed of Tertiary-age rocks. An exception is noted for the Gardiner River, in Reach PC1, which drains sparsely vegetated and steep Cretaceous shales that experience sheet erosion and debris flows during runoff events (Wagner 2006). The extent of rangeland and agricultural lands is positively correlated with suspended sediment concentrations (Miller et al. 2005). Channel scour and erosion also contribute sediment Frankforter et al. 2015); Lambing and Cleasby 2006).

The upper Yellowstone River has a much higher mean annual load of suspended sediment than the lower river but considerably lower than the Powder River, one of its major tributaries. The upper river had a Q1.5 yield of over 36 tons per year per square kilometer versus about 1.5 in the lower river (Klimetz et al. 2009). By comparison, the same mean annual yield in the largely free-flowing Powder River basin was 60 tons/year/km^2. The Powder River Basin, which accounts for only about 5 percent of the annual streamflow at Sidney, contributes 30 percent of the annual sediment load to the Yellowstone River (Klimetz et al. 2009). Figure 4-98 and Figure 4-99 depict sediment concentrations and load at the Sidney USGS station.

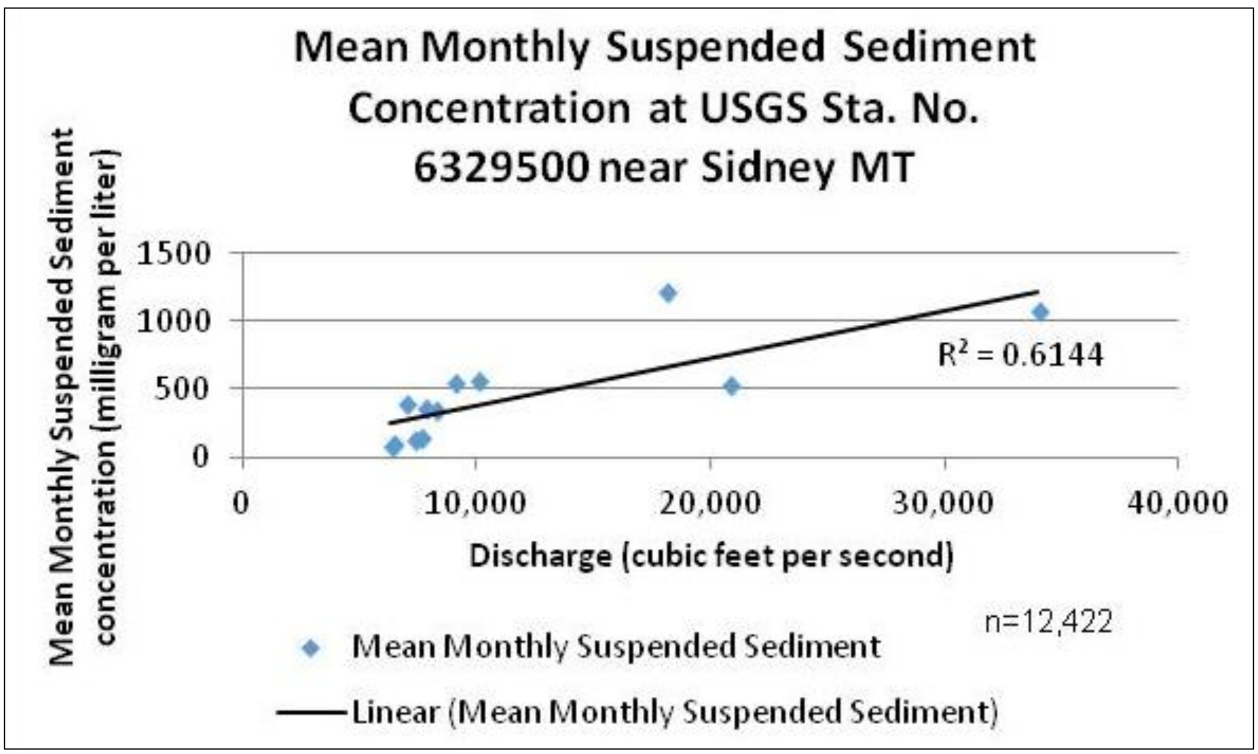


Figure 4-98 Mean monthly sediment concentrations of Yellowstone River near Sidney
Note: *Concentrations are fairly well correlated to discharge as evidenced by the slope of the trend line*

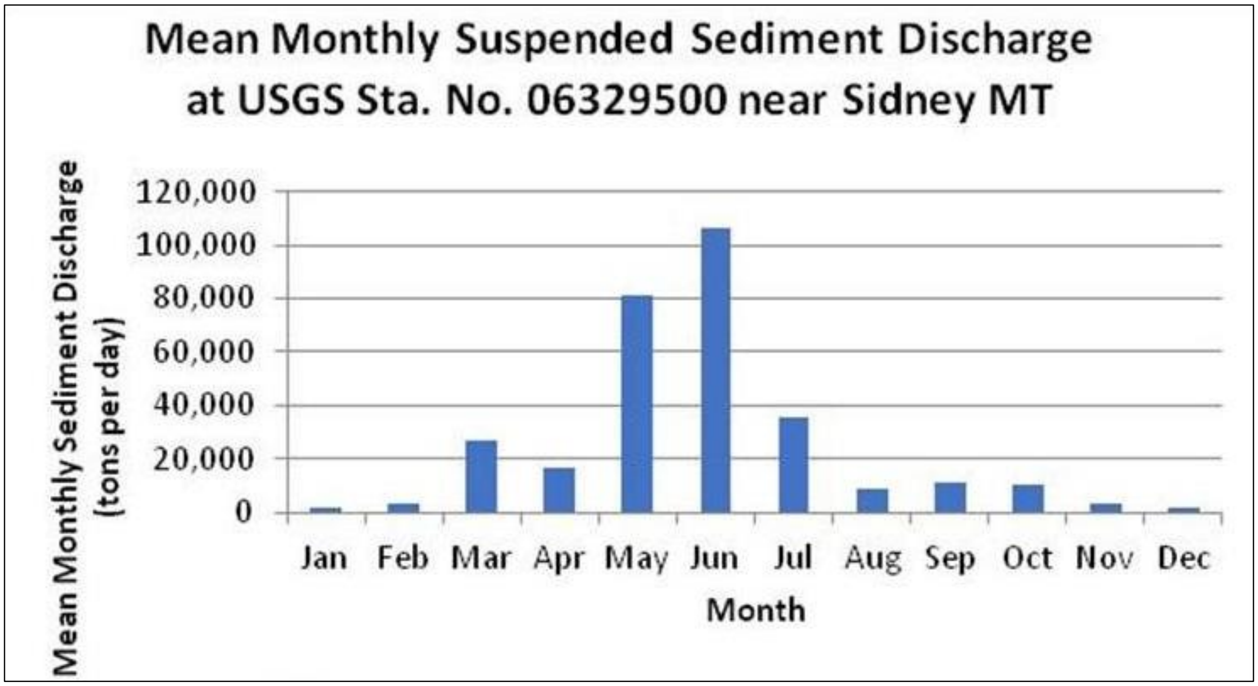


Figure 4-99 Mean monthly sediment load carried by the Yellowstone River near Sidney
Note: Load peaks in June at maximum spring runoff

Irrigation practices in the Clarks Fork Basin, along with natural factors, are recognized as a major source of suspended sediment at Billings (Knapton and Bahls 1993). The Clarks Fork had the maximum suspended sediment yield in the basin (400 tons per square mile) during the 1999–2001 sampling effort for the NAWQA program (Peterson et al. 2004). Irrigation practices contribute dissolved solids in the Clarks Fork, Wind/Bighorn River, and Powder River basins, while oil and gas development contributes suspended solids in the Wind/Bighorn and Powder River basins (Zelt et al. 1999).

As mentioned earlier and depicted in Figure 4-97, the active river channel is also a sizeable source of sediment (Frankforter et al. 2015, in review; Miller et al. 2005), which contributes total phosphorus to the Yellowstone system's load according to the SPARROW model results.

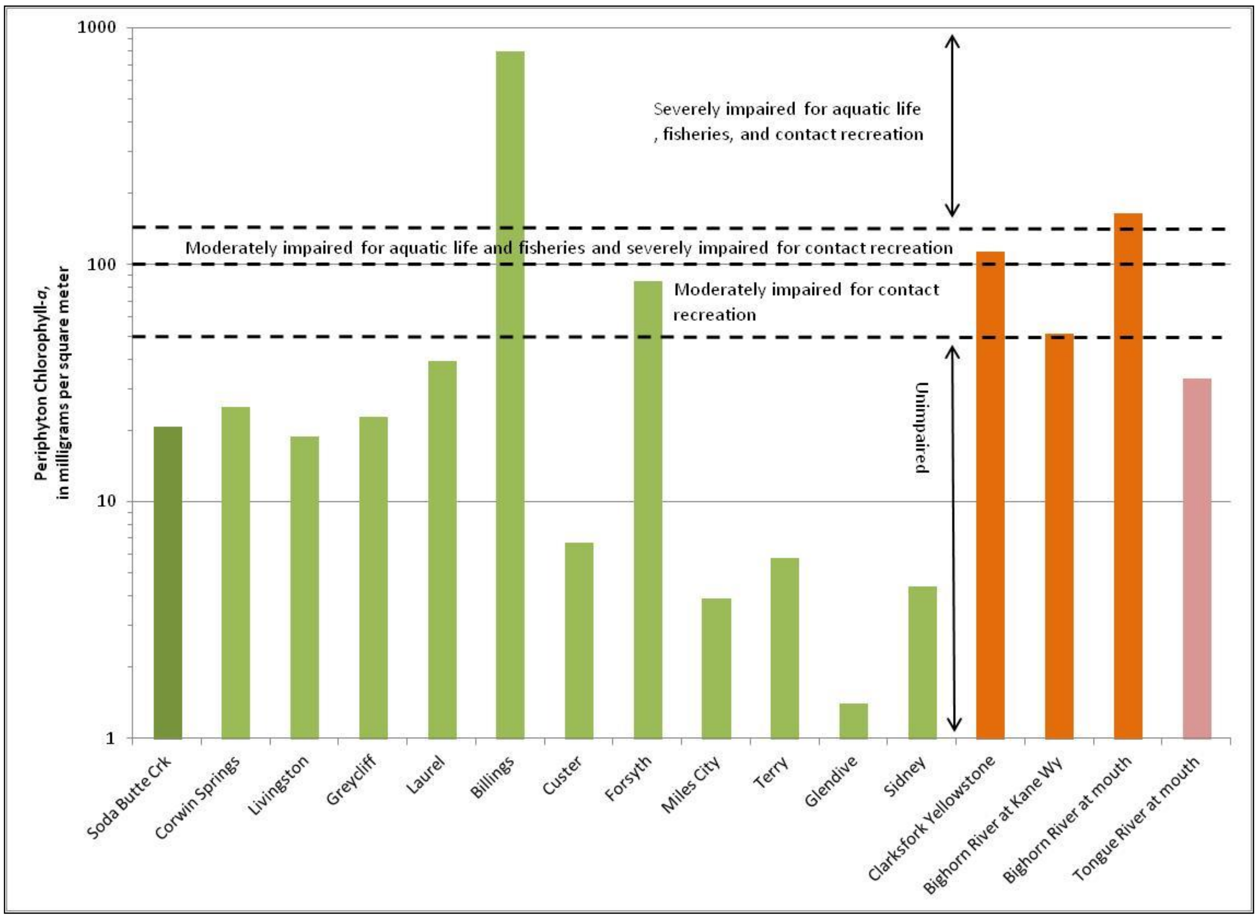
Alterations to the hydrology and sediment content of the Bighorn River have demonstrably affected the water quality and ecology of the Yellowstone River. The Bighorn drainage is rated as having the fifth-highest mean annual suspended sediment yield of all rivers in the Northwestern Great Plains Ecoregion (Klimetz et al. 2009). Operation of Yellowtail dam has substantially reduced sediment delivery to the Yellowstone River. Prior to the dam's completion in 1966, annual sediment delivery at the mouth of the Bighorn River was estimated at 7.2 million tons, but post-dam, sediment production has been estimated at 1.5 million tons per year, which represents an 80 percent decline (Silverman and Tomlinson 1984). The US Army Corps of Engineers estimated sediment capture in the reservoir to be in the range of 3,200 acre-feet per year (2010).

The creation of Yellowtail dam created a highly used non-native trout fishery as a result of reduced river temperatures and sediment load. These consequences have major negative impacts in the Yellowstone River and include a modified hydrologic regime (see Section 4.3 Hydrology), geomorphic impact (e.g., the loss of side channels) (Godaire 2009), reduced sediment delivery and transport (Silverman and Tomlinson 1984), and seasonal alterations of water temperature. Hydrologic alterations and impacts related to turbidity and water temperature are known to affect movement and use of habitat by warmwater fish (McMahon and Gardner 2001 cited in Yeager et al. 2005).

4.6.5 Biological Data

4.6.5.1 Periphyton

Algal biomass, particularly that of periphyton—also known as "benthic algae"—is a key indicator of water quality impairment due to nutrient enrichment in the Yellowstone River. The state of Montana established the threshold of chlorophyll *a* density >150 mg/m^2 as the numeric standard for nuisance algal growth (Flynn and Suplee 2013). Algal biomass, measured during an August 2000 USGS study, was largest in the middle segments of the Yellowstone River near Billings and Forsyth (Peterson et al. 2001) (Figure 4-100). In the figure Yellowstone River sites in light green are upstream to downstream. Values reflect nutrient enrichment from natural, agricultural, and rural residential sources. It also was high in the Clarks Fork of the Yellowstone River and the Bighorn River. The maximum concentrations of chlorophyll *a* detected in the Yellowstone River were at Billings (800 mg/m^2), downstream from the confluence with the Clarks Fork of the Yellowstone River, and at Forsyth (85 mg/m^2), downstream from the confluence of the Bighorn River. By comparison, chlorophyll *a* concentrations were 110 mg/m^2 in the Clarks Fork and 160 mg/m2 in the Bighorn River at the mouth (Peterson 2009; Peterson and Porter 2002).



Source: Peterson 2009

Figure 4-100 Periphyton chlorophyll$_a$ concentrations from August 2000

Note: *Concentrations in some Yellowstone River Basin streams exceeded criteria for the protection of beneficial uses according to criteria established by the MDEQ (2012a)*

Algal indicators or nutrient enrichment or eutrophication increased from very low levels at Corwin Springs to nearly 50 percent of the periphyton community in the middle segment of the Yellowstone River. Relatively large percentages of algae, whose growth is enhanced by organic sources of nitrogen, were found in the Yellowstone River at Sidney, Clarks Fork of the Yellowstone River (at Edgar), and at the mouth of the Bighorn River.

Excellent water clarity (low turbidity) contributes to algal productivity upstream of Custer. In the lower Yellowstone River, turbidity likely limits algal growth as the system changes from a periphyton-dominated system to a phytoplankton-dominated system. Peterson and Porter (2002) report that algal biomass and related measures of algal communities better reflect the trophic status of the Yellowstone River than do concentrations of dissolved or total nutrients.

4.6.5.2 Macroalgae

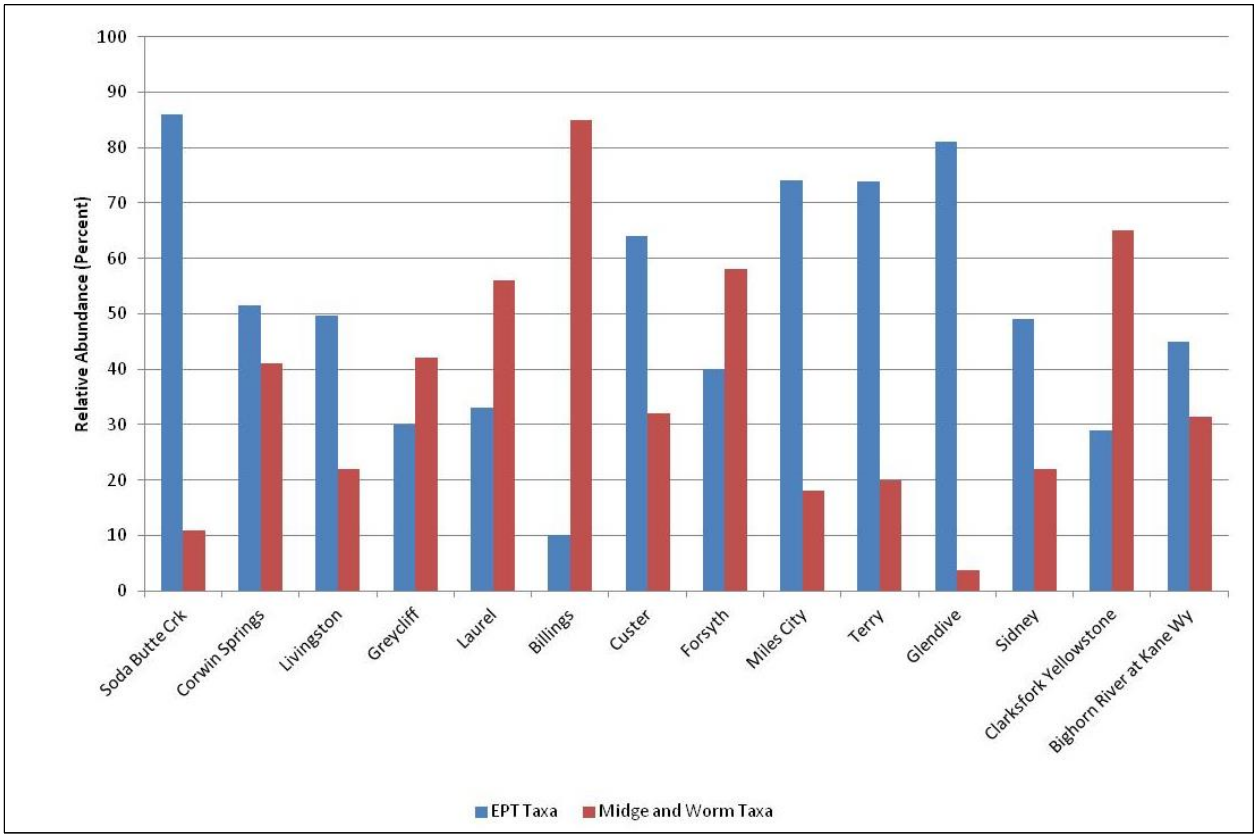
The biomass of macroalgae (filamentous algae) results followed a similar pattern in that maximum values occurred in the Billings area (490 grams per square meter (g/m^2)) and ranged from about 20 g/m^2 at Laurel and Forsyth to above 100 g/m^2 at Big Timber. Macroalgae biomass typically exceeded microalgae biomass by at least one order of magnitude at most sites and by two orders of magnitude at Miles City (Peterson and Porter 2002).

4.6.5.3 Macroinvertebrates

Aquatic invertebrates (aquatic insects, worms, and snails) are commonly used to assess stream quality and reflect the impacts of eutrophication, alterations to long-term water chemistry, or physical disturbance of terrestrial and aquatic habitat (Barbour et al. 1999). Results are described in terms of various biotic indices calculated to reflect shifts in the abundance and composition of macroinvertebrate communities relative to their tolerance of various disturbances.

Results of the 1999–2001 NAWQA study of macroinvertebrates in the Yellowstone River indicated that mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisfly species (Tricoptera; also known as EPT) were predominant in the upper segments of the Yellowstone River at Corwin Springs and Livingston, as well as in lower segments of the river from Miles City to Sidney (Figure 4-101). Greater percentages of pollution intolerant mayflies, stoneflies, and caddisflies (EPT) in the upper and lower Yellowstone River indicate better water quality and aquatic habitat. The lower percentages in the middle Yellowstone River possibly indicate degraded conditions (Peterson 2009), though additional study is in order to confirm this.

Tolerant taxa dominated the Yellowstone River invertebrate community at Billings and Forsyth, sites immediately downstream from the two largest tributaries, the Clarks Fork of the Yellowstone River and the Yellowstone and Bighorn rivers. Based on EPT abundance, the data indicated degraded conditions in the Clarks Fork, but relatively good conditions in mountain tributaries (Peterson et al. 2004; Peterson 2009).



Source: Peterson et al. 2004

Figure 4-101 Relative abundance of macroinvertebrate taxa at Yellowstone Basin sites

Note: Pollution tolerant midges and worms dominate aquatic insect communities in the Clarks Fork and at Yellowstone River sites below the confluence of the Bighorn

4.6.5.4 Fish

The community composition and physical health of fish species reflect the quality of their environment, (Barbour et al. 1999). A discussion of fish abundance and distribution in the Yellowstone River and their relationship to the Cumulative Effects Analysis (CEA) is in Section 4.9. Results are presented here relative to water quality considerations. The analysis by Peterson et al. (2004) of fish communities in the Yellowstone River Basin 1998 to 2001 indicated some differences in fish community composition. Species in the upper river are less tolerant of sediment while those in the lower river are more tolerant. Species diversity increased going downstream as did tolerance to warm, turbid water. The proportion of native species increased to some extent in the lower river compared to the upper river where rainbow, brown, and brook trout were introduced to enhance the sport fishery (Peterson et al. 2004).

External anomalies such as skin lesions, deformities, eroded fins, and tumors may be a sign of chemical contamination or environmental stress. The highest rates of external anomalies were noted in fish from Billings (Reach B2) and Forsyth (Reach C10), where about 15–20 percent of fish had skin lesions or abraded fins. The anomalies occurred at higher rates in members of the sucker family that dwell on the bed of the river. Rates of anomalies noted in fish at Corwin Springs and Sidney were below 5 percent while those in the Clarks Fork of the Yellowstone River and Bighorn River were both above 5 percent. Later fish sampling in 2002–2003 in Forsyth showed reduced rates of external anomalies (Peterson et al. 2004); however, comparable data was not available for the other Yellowstone sites.

4.6.5.5 Biological Summary for AUID and Reaches

A detailed summary of biological and related characteristics for the 12 Yellowstone River AUIDs and their equivalent 88 CEA reaches is presented in Appendix 5 (Water Quality).

4.6.6 Beneficial Use Support Matrices

Under the federal Clean Water Act (CWA) [33 U.S.C. §1251 et. seq. (1972)], all surface waters of the Yellowstone River in Montana and North Dakota are designated with specific beneficial uses (e.g., agriculture (livestock and irrigation), industrial, drinking water (with treatment), recreation, fish and aquatic life) and have been assigned to "use classes" that categorize the associated beneficial uses. Water quality standards are established to protect the beneficial uses (Mohr 2012). Each use class has associated standards that specify how clean the water must be to support the associated use. The standards are used as a measuring stick to indicate if waters are meeting or are not meeting water quality goals. Montana's and North Dakota's water quality standards are both numeric and narrative in nature.

Montana's water quality use classes and associated beneficial uses are found in the Annotated Rules of Montana Subchapter 17.30.6. North Dakota's rules (North Dakota Administrative Code 33-16-02.1) are similar as they both mimic language in the CWA. The designated water quality use classes and associated beneficial uses of the Yellowstone River within the scope of the CEA are shown in Appendix 5 (Water Quality).

The MDEQ has divided the mainstem of the Yellowstone River into 11 segments (assessment units) for the purposes of establishing beneficial uses and conducting beneficial use assessments. North Dakota has designated one assessment unit for the Yellowstone River. States are required to report the status and trends of the state's waters in the 305(b) Water Quality Assessment Report. States are also required to track and submit a list of impaired waters in need of total maximum daily loads (TMDLs). This list, known as the 303(d) list, and the 305(b) reports for each state have been combined into an integrated report and submitted in even-numbered years. The most recent integrated report for Montana was issued in May 2014 (MDEQ 2014a). The North Dakota Department of Health's Draft 2014 Integrated Report is not yet finalized at the time of this writing (P. Olson, NDDH personal communication on November 12, 2014). Detailed beneficial use support data for all 12 assessment units in Montana and North Dakota are provided in Table 4-12.

Table 4-12
2014 Integrated Report Listings for the Yellowstone River in Montana and North Dakota

AUID	Description	Length (mi.)	Use Class[1]	Water Quality Category[2]	Yellowstone CEA Reaches
MT43B001_011	Wyoming Border to YNP Boundary	8.68	A-1	5	PC 1
Beneficial Use Support Determination—The 2006 Montana 303(d) list reports that the coldwater fishery and drinking water beneficial uses are partially supported due to metals, nutrients, siltation, and suspended solids likely caused by highway/road/bridge construction and natural sources. Additionally, the 2006 303(d) list added arsenic as a cause of impairment associated with the drinking water beneficial use. This segment will be reassessed following completion of the large river protocols. Not reassessed 2008, 2010, 2012, or 2014. Aquatic life and drinking water not supported. Ag and Contact Recreation not assessed.					
MT43B001_010	YNP Boundary to Reese Creek	4.79	A-1	5	PC1
Beneficial Use Support Determination—The 2006 303(d) list reports that the coldwater fishery and drinking water beneficial uses are partially supported due to metals, nutrients (ammonia, NO3-NO2), siltation, and suspended solids due to highway/road/bridge construction and natural sources. Additionally, the 2006 303(d) list added the following three metals: arsenic, copper, and lead. It was noted that issues associated with nutrients and arsenic may be natural due to geothermic inputs from springs. Further analysis is necessary. This segment will also be reassessed following completion of the large river protocols. Not reassessed 2008, 2010, 2012, or 2014.					
MT43B003_010	Reece Creek to Bridger Creek	119.0	B-1	4C	PC2 to A7
Beneficial Use Support Determination— Limited data were available for this segment. Aquatic Life & Cold Water Fishery: The 1998 habitat assessment shows significant habitat impairment (streambank alteration) in this reach. Arsenic exceeded the human health standard, and since there are mines present on tributaries of this segment, non-natural source contributions are possible; thus the drinking water beneficial use is non-support as a result of the water quality exceedances. Coldwater fishery and aquatic life not supporting due to habitat alteration. Not reassessed since prior to 2006. Ag, Drinking Water, and Contact Recreation not assessed. Not assessed for 2014 cycle.					
MT43F001_012	Bridger Creek to Laurel PWS	56.31	B-1	2	A8 to A17
Beneficial Use Support Determination—1996 listings were unionized ammonia, salinity, TDS, chloride, and suspended solids but were dropped in 2006 cycle. Aquatic Life, Primary Contact Recreation and Agriculture: Fully Supporting. Drinking Water: Not Assessed due to insufficient information. Not reassessed 2008 thru 2014 cycles.					
MT43F001_011	Laurel PWS to Billings PWS	19.4	B-2	5	A18 to B2
Beneficial Use Support Determination— Reach D described as heavily impacted, having lost (as a result of channel simplification) 24,000 ft (14%) of its channel length since 1950s. Study suggests that fisheries experts should evaluate the effect of such channel loss on the fishery. Bank armoring (riprap, etc.) is 39% in this reach. Geomorphic study defines the reach upstream of Billings as unconfined braided, with high modification and 34% bank armoring. 2010 Cycle: The 1996 listing for unionized ammonia, alkalinity/TDS/chlorides, and suspended solids was removed due to later sampling which showed these constituents are at acceptable values. 2012 Cycle: As a result of the 2011 Silvertip pipeline break and documented oil spill, this segment is impaired (Aquatic Life and Primary Contact Recreation) for oil and grease until monitoring shows that spilled oil has been bio-remediated after the cleanup. Agriculture: Fully Supporting. Drinking Water: Not Assessed due to insufficient data. 2014 cycle: Not assessed.					

<table>
<tr><th>AUID</th><th>Description</th><th>Length (mi.)</th><th>Use Class[1]</th><th>Water Quality Category[2]</th><th>Yellowstone CEA Reaches</th></tr>
<tr><td>MT43F001_010</td><td>Billings PWS to Huntley Div. Dam</td><td>10.62</td><td>B-3</td><td>5,5N</td><td>B3 to B4</td></tr>
<tr><td colspan="6">Beneficial Use Support Determination—2006 Cycle: This general reach of the Yellowstone River was listed as only partially supporting its aquatic life, warmwater fishery, drinking water and recreation beneficial uses due to salinity/TDS/chlorides, suspended solids, and unionized ammonia.
2008 and 2010 Not assessed. Reach length redefined.
2012 Cycle: Aquatic Life and Primary Contact Recreation beneficial uses for this Assessment Unit are being listed for Oil and Grease as a result of the Silvertip Pipeline break.
2014 Cycle: User defined category updated from 2B to 5N during 2014 cycle.
Aquatic Life, Primary Contact Recreation, and Drinking Water: Not Supporting. Agriculture: Fully Supporting.</td></tr>
<tr><td>MT43Q001_011</td><td>Huntley Div. Dam to Bighorn River</td><td>58.31</td><td>B-3</td><td>5</td><td>B5 to B12</td></tr>
<tr><td colspan="6">Beneficial Use Support Determination—1996: This assessment unit was listed as only partially supporting its aquatic life, warmwater fishery, drinking water supply and recreation beneficial uses due to salinity/TDS/chlorides, suspended solids and unionized ammonia likely caused by agriculture, industrial point sources, irrigated crop production, municipal point sources and natural sources.
2000-2004: Insufficient information to evaluate this reach.
2006: Because large river protocols are being developed but not yet applied, the 2006 303(d) list will conservatively report that the aquatic life, warmwater fishery, drinking water supply and recreation beneficial uses are partially supported due to salinity/TDS/chlorides, suspended solids and unionized ammonia likely caused by agriculture, industrial point sources, irrigated crop production, municipal point sources and natural sources. This segment will be reassessed following completion of the large river protocols.
2008-2010: Not assessed these cycles.
2012: Aquatic Life and Primary Contact Recreation beneficial uses are being listed for Oil and Grease as a result of the Silvertip Pipeline break.
2014: Not assessed this cycle. Aquatic Life and Primary Contact Recreation: Not Supporting. Agriculture and Drinking Water: Not assessed due to insufficient data.</td></tr>
<tr><td>MT42K001_020</td><td>Bighorn River to Cartersville Div. Dam</td><td>59.51</td><td>B-3</td><td>4C</td><td>C1 to C11</td></tr>
<tr><td colspan="6">Beneficial Use Support Determination—2004: Aquatic Life: Not supporting; Agriculture: Fully Supporting. Drinking Water and Contact Recreation: Not Assessed due to insufficient data.
Not Assessed 2006-2014 Cycles.</td></tr>
<tr><td>MT42K001_010</td><td>Cartersville Div. Dam to Powder River</td><td>88.73</td><td>B-3</td><td>5</td><td>C12 to C21</td></tr>
<tr><td colspan="6">Beneficial Use Support Determination—1996: The segment code for this reach of the Yellowstone River was MT42K001-1. It was listed for metals, nutrients, other habitat alterations, pathogens, salinity/TDS/chlorides, suspended solids, and pH.
2000-2004: This segment was determined to lack sufficient credible data and therefore was not assessed for the aquatic life, warmwater fishery, drinking water, and contact recreation beneficial uses. It was considered fully supporting for agriculture and industry uses.</td></tr>
</table>

<table>
<tr><th>AUID</th><th>Description</th><th>Length (mi.)</th><th>Use Class[1]</th><th>Water Quality Category[2]</th><th>Yellowstone CEA Reaches</th></tr>
<tr><td>42M001_012</td><td>Powder River to Lower Yellowstone Div. Dam</td><td>76.73</td><td>B-3</td><td>4C</td><td>D1 to D9</td></tr>
<tr><td colspan="6">Beneficial Use Support Determination[3]—2006: There is still insufficient information to assess any use, including the agriculture and industry uses. All uses need to be evaluated with more updated information integrating the anticipated large river protocols. The 2006 303(d) list (as did the 1996 list) will conservatively report that the aquatic life, warmwater fishery, drinking water supply, and contact recreation beneficial uses are partially supported due to metals, nutrients, other habitat alterations, alkalinity/TDS/chlorides, suspended solids, bacteria, and pH likely caused by agriculture, irrigated crop production, municipal point sources, natural sources, rangeland and streambank modification/destabilization. Regarding the pathogen listing in 1996: changes to water quality standards prevent the general "pathogens" listing from being carried forward. The current bacteria Standard and ADB entry is E. coli, which is too specific to translate a general pathogen listing. Additionally, the original basis for the pathogen listing is unknown. At present, there are no E.coli data for this stream. Therefore, this segment will be flagged for E. coli monitoring in 2007. This segment will also be reassessed following completion of the large river protocols.
2008-2014: No further assessment. Aquatic Life: Not Supporting; Agriculture, Drinking Water, and Primary Contact Recreation: Not Assessed due to insufficient information.</td></tr>
<tr><td>MT42M001_011</td><td>Lower Yellowstone Div. Dam to Border</td><td>53.67</td><td>B-3</td><td>5</td><td>D9 to D13</td></tr>
<tr><td colspan="6">Beneficial Use Support Determination—1996: This unit was listed as only partially supporting aquatic life, warmwater fishery, drinking water supply, recreation and swimmable beneficial uses due to metals, nutrients, habitat alterations, pathogens, salinity/TDS/chlorides, suspended solids and pH likely caused by agriculture, irrigated crop production, municipal point sources, natural sources, rangeland and streambank modification/destabilization.
2000-2004: Insufficient information to fully evaluate under revised use support determination procedures.
2006: In anticipation of large river assessment and sampling protocols, the 2006 303(d) list will conservatively report that the aquatic life, warmwater fishery, drinking water supply, and recreation beneficial uses are partially supported. Aquatic Life limitations noted as due to alteration in stream-side or littoral vegetative covers, chromium (total), copper, fish-passage barrier, lead, sedimentation/siltation, total dissolved solids, pH, nitrogen (total), and phosphorus (total) due to flow regulation/ and modification, streambank modification, irrigated crop production, rangeland, natural, and unknown sources. The following specific metals were added on the 2006 303(d) list: copper, lead, arsenic, and chromium. Pathogen listing for Contact Recreation was removed due to change in assessment procedures and water quality standards. Insufficient data at present.
2008-2014: No further assessment. Aquatic Life: Not Supporting; Agriculture, Drinking Water, and Contact Recreation: Fully Supporting.</td></tr>
<tr><td>ND-1010000-001-S_00</td><td>MT/ND border to confluence with Missouri</td><td>21.3</td><td>1</td><td>2</td><td>D14-16</td></tr>
<tr><td colspan="6">Beneficial Use Support Determination—North Dakota’s 1998 303(d) Report listed this assessment unit as impaired for Aquatic Life and Recreational Uses due to metals and bacteria, respectively. The 2002 303(d) report removed the Recreational impairment (bacteria) due to a lack of sufficient credible data and revised the Aquatic Life support impaired listing to Threatened (selenium). The 2004 303(d) report amended the listing to Fully Supporting but Threatened due to Trace Metals (copper, lead, selenium and zinc) and Pesticides (atrazine and simazine). The assessment unit was delisted in the 2006 303(d) report because water quality data at the USGS Sidney gage (06329500) showed no exceedances for metals and pesticides.
2008 – 2014: No further assessment. Fully supporting all uses.</td></tr>
</table>

Notes:

1. Use classes defined as follows:

- *Montana waters classified A-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment for removal of naturally present impurities. Water quality must be maintained suitable for bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.*
- *Montana waters classified B-1 are to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply. The primary objective in treating surface water is to remove or inactivate microbiological contaminants (e.g., viruses, bacteria, and protozoa) that can cause disease. Water contaminated with animal or human waste can transmit diseases to humans; therefore, adequate treatment of microbiological contaminants is essential in order to avoid acute health effects. People with compromised immune systems, such as infants, the elderly, the ill, and HIV-positive individuals, may be especially vulnerable to water-borne diseases.*
- *Montana waters classified B-2 are to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.*
- *Montana waters classified B-3 are to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.*
- *Use Class I streams in North Dakota shall be suitable for the propagation or protection, or both, of resident fish species and other aquatic biota and for swimming, boating, and other water recreation. The quality of the waters shall be suitable for irrigation, stock watering, and wildlife without injurious effects. After treatment consisting of coagulation, settling, filtration, and chlorination, or equivalent treatment processes, the water quality shall meet the bacteriological, physical, and chemical requirements of the department for municipal or domestic use.*

2. Under the federal Clean Water Act, the U.S. Environmental Protection Agency (EPA) requires that total maximum daily loads be developed for waters impaired by "pollutants," such as nutrients, sediment, or metals. TMDLs are not required for waters impaired solely by "pollution," (e.g., flow alterations or habitat degradation). The Montana and North Dakota integrated reports place all waters into five categories based on assessment status as per guidance from the EPA:

- *Category 1: Waters for which all applicable beneficial uses have been assessed and all uses have been determined to be fully supported.*
- *Category 2: Waters for which beneficial uses that have been assessed are fully supported, but some applicable uses have not been assessed.*
- *Category 3: Waters for which there is insufficient data to assess the use support of any applicable beneficial use, so no use support determinations have been made.*
- *Category 4: Waters where one or more beneficial uses have been assessed as being impaired or threatened; however, all necessary TMDLs either have been completed or are not required.*
    - *Subcategory 4A: All TMDLs needed to rectify all identified threats or impairments have been completed and approved.*
    - *Subcategory 4B: Water bodies are on lands where "other pollution control requirements required by local, State, or Federal authority" (see 40 CFR 130.7(b)(1)(iii)) are in place, are expected to address all water body-pollutant combinations, and attain all water quality standards in a reasonable period of time. These control requirements act "in lieu of" a TMDL, thus no actual TMDLs are required.*
    - *Subcategory 4C: Identified threats or impairments result from pollution categories (e.g., dewatering or habitat modification) and, thus, the calculation of a TMDL is not required.*
- *Category 5: Waters where one or more applicable beneficial uses have been assessed as being impaired or threatened, and a TMDL is required to address the factors causing the impairment or threat.*
    - *Subcategory 5N: Available data and/or information indicate that a water quality standard is exceeded because of an apparent natural absent any identified manmade sources.*

Sources: *Detailed assessment reports accessed through the Montana Clean Water Act Information Center and within Montana's biannual Water Quality Integrated Reports [305(b) and 303(d) reports] both accessed online November 25, 2014, at http://deq.mt.gov/wqinfo/CWAIC/default.mcpx. North Dakota Beneficial Use Support interpretations summarized from North Dakota's Water Quality Integrated Reports [305(b) and 303(d) reports] accessed online November 25, 2014, at https://www.ndhealth.gov/WQ/SW/A_Publications.htm.*

4.6.7 Transportation: Impacts on Water Quality

4.6.7.1 Roads: Runoff Pollution and Hazardous Material Spills

For the purposes of this report, the transportation discussion considers impacts of railroads, county and state roadways, and Interstate 90/94. Impacts of city and municipal roads and other transportation-related impacts not addressed here are discussed in Section 4.6.9 Urban/Exurban Development. The matrix of transportation system features along and within the Yellowstone River corridor potentially contributes to nonpoint source pollution through contaminated runoff from roads and bridges, atmospheric deposition of nitrogen oxides, floodplain and river channel encroachment, accidental spills, road application of winter traction materials, and construction activities (MDEQ 2012b). Sediment, nutrients, dissolved solids, metals, and hydrocarbons (gasoline, oil, and grease products) are all potential pollutants of surface waters that might be generated by the transportation system when adequate pollution controls are not in place. Additionally, physical habitat loss and degradation is associated with the actual construction of transportation features.

The extent of transportation facilities within the Cumulative Effects Analysis (CEA) project area and individual reaches is discussed in detail in Section 4.2 Land Use Change. The 100-year inundation zone corridor contains over 40 miles of transportation features, with railroads being the dominant feature. Figure 4-102 depicts the relative share of transportation features by type. No specific data or studies pertinent to the Yellowstone River system directly measure or assess the impact of transportation systems on classic measures of water quality in the Yellowstone River; however, increased levels of semi-volatile organic compounds (SVOC) and polynuclear aromatic hydrocarbons (PAH) were noted for the Billings area (Reach B2) in Section 4.6.3.7. Potential sources of elevated levels of SVOCs and PAHs may be transportation-related as well as industrial sources.

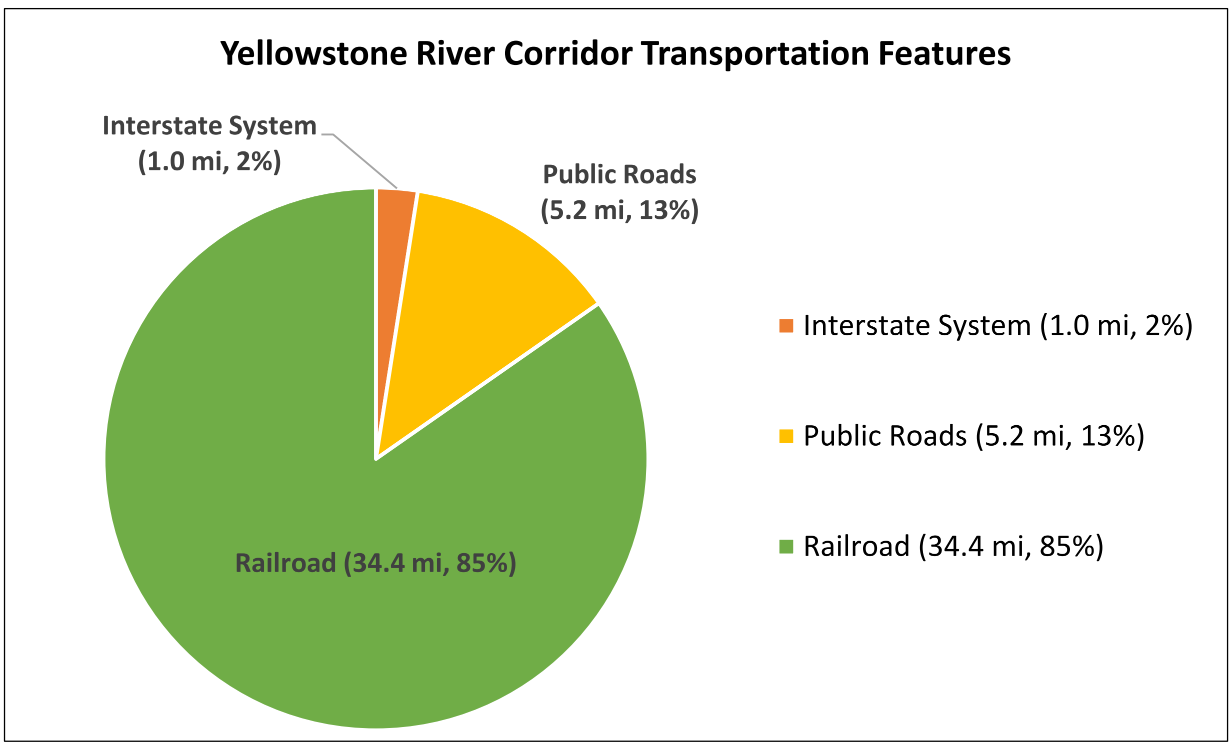


Figure 4-102 Transportation features within the Yellowstone River 100-year inundation zone corridor total over 40.5 miles in length

Eighty-five percent of all transportation features within the 100-year inundation zone are related to the railroad. Given the railroad's proximity to the channel and the hazardous nature of some products transported by rail, there is a high potential for impacts to water quality due to contaminated runoff or spills to the river. Currently, an unknown quantity of petroleum, industrial solvents, and other hazardous materials travel in tank cars daily along the state's roads, the interstate highway system, and active railroad tracks. The industry has taken steps to minimize the hazard of spills, but the possibility remains due to the extent of the railroad's proximity to the channel, particularly in reaches C10, C11, C12, C14, and D10.

The interstate highway and public roads offer less potential to impact water quality as they typically are located at a greater distance from the river and have wider right-of-ways that can act as traps and filters for any contaminated runoff or spills, except at bridge crossings. Poorly maintained bridges can sometimes be a sizeable source of sediment and road runoff delivered to a stream; however, most bridges on the Yellowstone River are by nature larger structures and are constructed in a way that minimizes this potential.

The Physical Features Inventory (2001) identified 54 bridges crossing the Yellowstone River. Figure 4-103 illustrates their relative distribution by county and type. Twenty of the bridges are owned by county governments and an equal number by the state and interstate highway system. In general, due in part to the number and volume of materials transported, the greatest risk of spills is likely to occur at railroad, state highway, and interstate bridges.

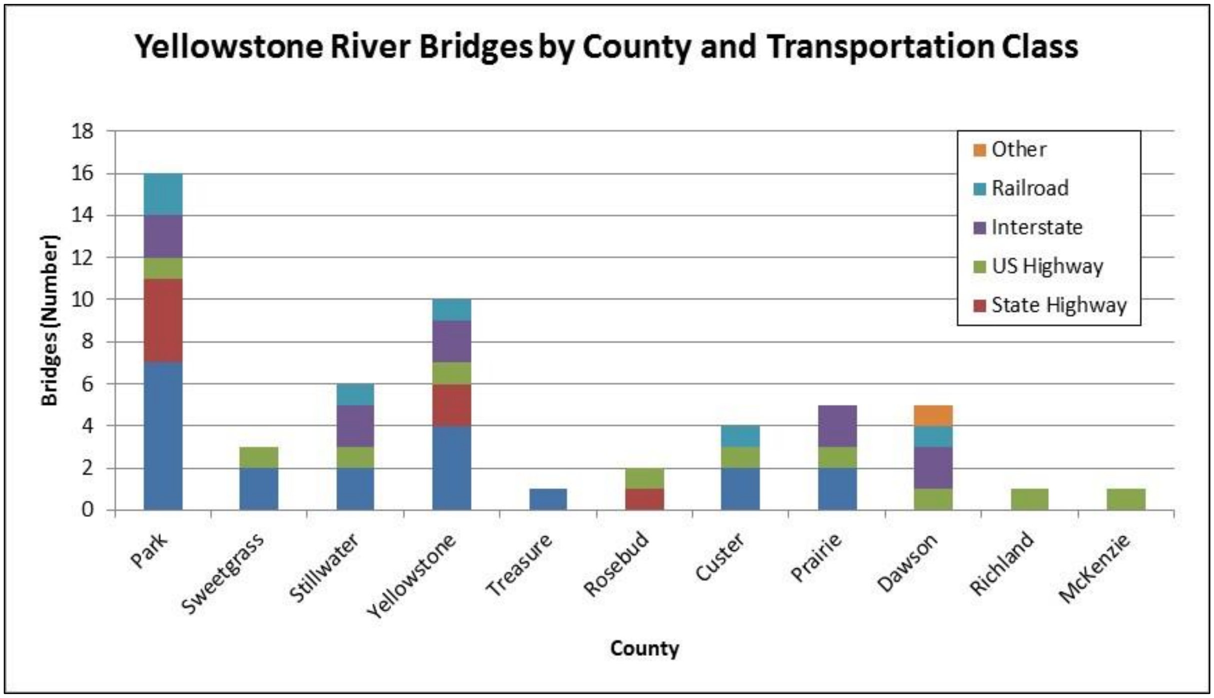


Figure 4-103 Yellowstone River bridges by county and transportation class
Note: *About one-third of all Yellowstone River bridges are in Park County and about 20 percent in Yellowstone County*

According to the Burlington Northern Santa Fe Railroad (BNSF), it is in the process of developing a Yellowstone Sub-Area Contingency Plan in conjunction with the EPA Region 8 Emergency Response Unit and the Montana-Wyoming Oil Spill Cooperative (Winslow, BNSF personal communication on

January 15, 2015). BNSF uses a 3-part prevention program to reduce the risk and extent of material releases that includes track inspections/maintenance, training for shippers and railroad workers, and spill response time. Still, the federal Pipeline and Hazardous Material Safety Administration (2015) reports that, while train derailments dropped by half between 2004 and 2014, there were 141 unintentional petroleum releases last year—a record level. The organization predicts that 40 times more oil will be handled by rail in 2015 than in 2005, so due diligence and coordination is needed to protect Yellowstone River resources.

Chloride contamination in transportation system runoff can adversely affect water quality, in particular, aquatic life (Corsi et al. 2010). Chloride-based de-icing product use is widespread in Montana. While the Yellowstone River is likely too large to experience widespread impacts of chloride-laden runoff, appropriate incorporation of approved stormwater management practices helps to control this potential pollution source.

4.6.7.2 Pipelines: Rupture and Spills

A pipeline risk assessment report prepared for the Yellowstone River Conservation District Council (Atkins 2012) indicates the presence of 39 pipelines intersecting the Yellowstone River Channel Migration Zone (DTM and AGI 2012) at 21 crossings between Gardiner and the confluence with the Missouri River. Thirty of the pipelines cross the channel while nine pipelines are located within a designated Channel Migration Zone. Exposure due to scour and channel migration was noted as the greatest threat to pipeline safety. Raw crude oil, petroleum products, liquefied natural gas, and natural gas are the products transported by pipelines within the corridor. Under criteria developed for the report, the study found that 32 of the pipelines represented low risk, one represented moderate risk, and six represented no risk under their current operation as they are no longer in use. Figure 4-104 provides the number of occurrences by geomorphic reach. Reaches B1 and B2 in Yellowstone County have the greatest number of pipelines. Figure 4-105 provides the commodities carried by the pipelines identified in the Atkins report.

The pipeline risk assessment report was prepared as a result of the July 1, 2011 rupture of the Exxon Mobil Silvertip Pipeline near Billings, Montana. A reported 63,000 gallons of crude oil were spilled into the Yellowstone River near the peak 2011 stream discharge as a result of the rupture. More than 80 fish were found dead as a result, however, given the very high flows and long interval between the spill and the time fish recovery began, it is likely that many more fish and other aquatic and terrestrial organisms were negatively affected. Estimated cost of the spill and cleanup was in the millions of dollars. CEA Reaches below the spill site (A18 to B4) are listed on the 2014 Montana 303(d) list as having the aquatic life and contact recreation beneficial uses impaired from that spill. While recent samples have tested below state water quality standards, it is apparent that there is still oil residing in the substrate as a result of the Silvertip pipeline spill. Until the oil is dissipated by biological degradation, it will continue to be listed (MDEQ 2014a).

On January 17, 2015, the 12-inch Poplar Pipeline operated by the Bridger Pipeline Company experienced a break and crude oil leak about six miles above Glendive, Montana. The pipeline break occurred under the river bed and initially caused crude oil to enter Glendive's municipal water supply where benzene was detected resulting in a shutdown of the water system for several days. An estimated 30,000 gallons of crude oil was released into the river. Due to extensive ice cover on the river, attempts to contain the spill were largely unsuccessful. The spill impacted an area at least 90 miles long and was confirmed as far downstream as Williston, North Dakota. Tests of fish tissue below the break confirmed the presence of PAHs prompting Montana Fish, Wildlife & Parks to issue a fish consumption advisory (MFWP 2015).

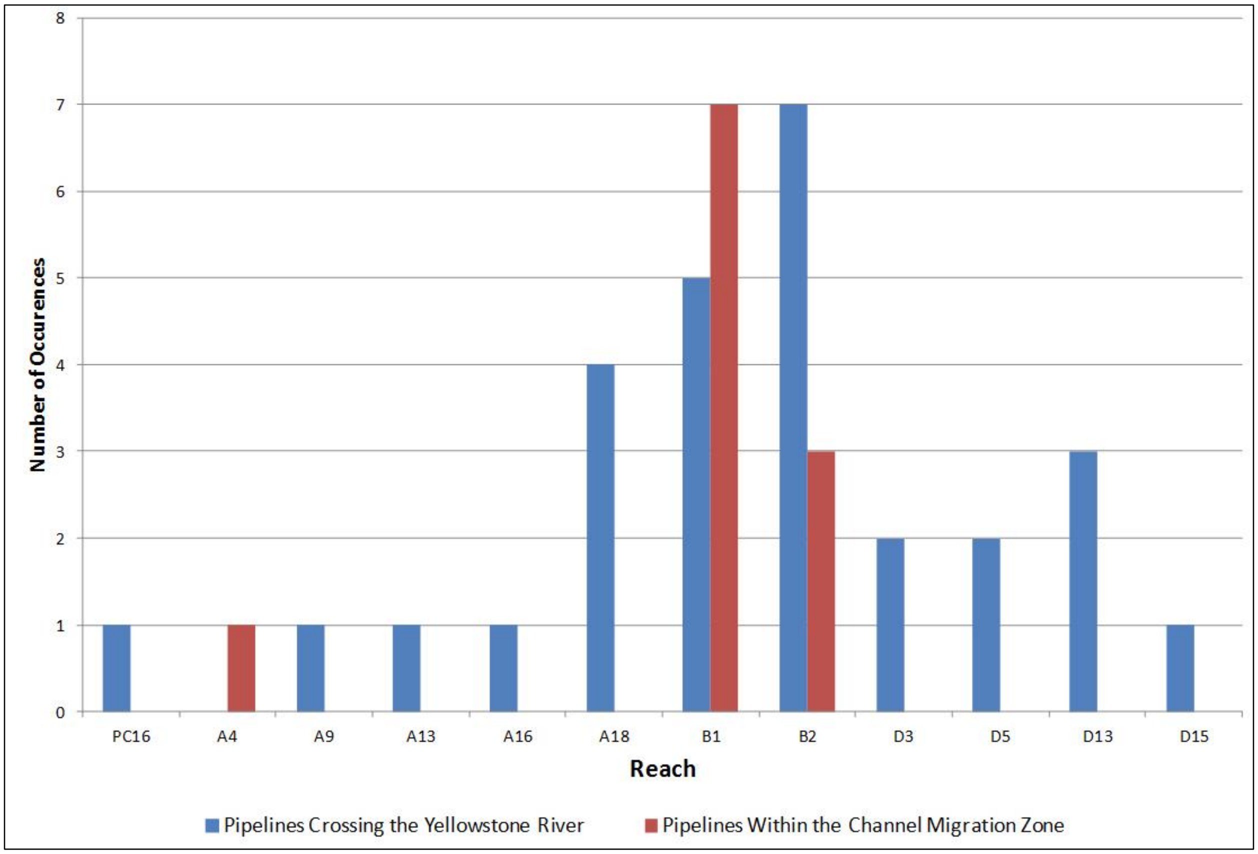
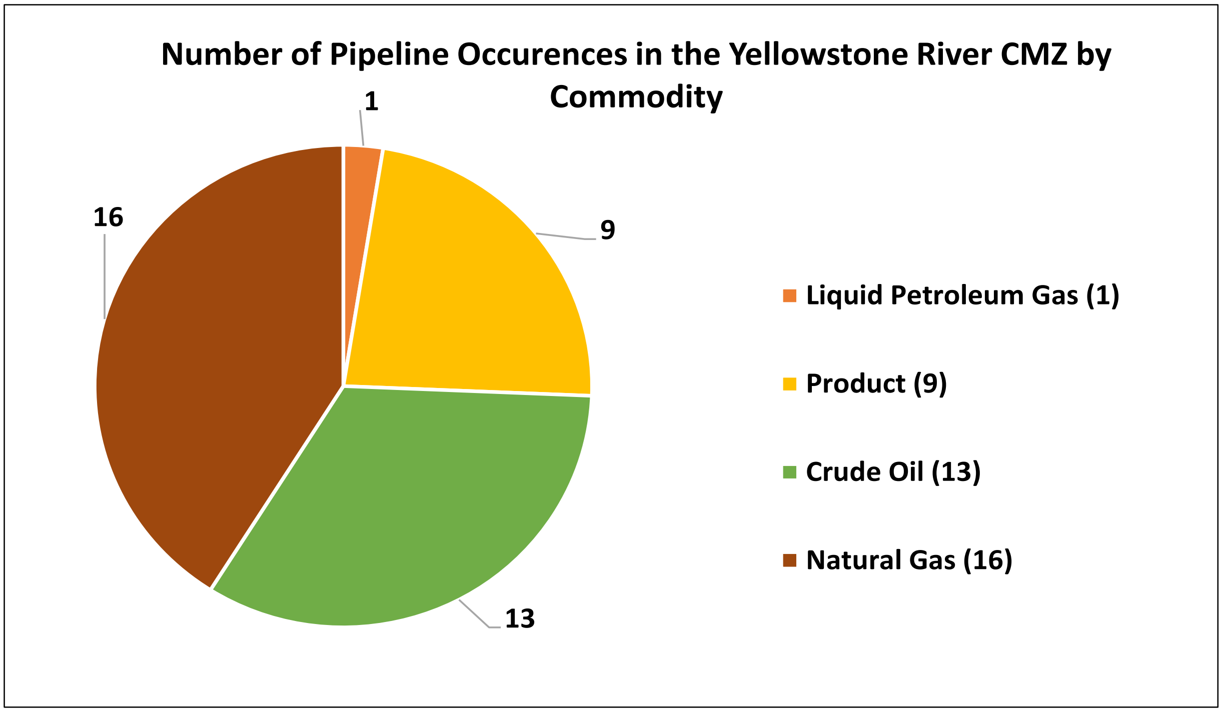


Figure 4-104 Yellowstone River pipeline occurrences by reach

Note: *Reaches B1 and B2 contain the greatest number of pipeline crossings within the CMZ*



Source: Atkins 2012

Figure 4-105 Number of pipeline occurrences within the Yellowstone River CMZ by commodity

While the threat to water quality posed by potential pipeline breakages cannot be quantified, it undoubtedly is high due to the immediate proximity of the pipeline crossings to surface water and the dynamic nature of the river. Both the Exxon Silvertip and the Poplar pipeline failures appear to be related to channel incision. Both lines were relatively old and had been installed by trenching rather than with newer directional drilling technology, which can place the line deeper under the river bed and set back further from the bankline. Directional drilling at an appropriate depth below the river bed should be utilized as a recommended management practice for all new pipeline crossings and replacement of crossings older than 20 years on the Yellowstone River to ensure they are properly installed.

Oil and gas production can also discharge pollutants to the river from leaking wastewater pipelines and breached or flooded brine and water storage pits. The number of spills related to oilfield wastewater or brine (saltwater) has been increasing as the industry expands. A recent review in North Dakota calculated that there have been several thousand such discharges since 2006 (Guerin 2015). Contaminants include chloride, salts, heavy metals, petroleum, and even radioactive materials. In 2006, a faulty plastic pipeline weld spilled an estimated 1 million gallons of brine into Charbonneau Creek—which discharges to the Yellowstone River in North Dakota—killing aquatic life and vegetation. The water and soil remained contaminated for years, impacting ranchers who used the water. A recent brine spill of about 3 million gallons in North Dakota near Williston contaminated two creeks and reached the Missouri River (Washington Post 2015). A reported 74 brine spills occurred in North Dakota in 2013.

The number of drill and well production pads within the river corridor in Region D is increasing rapidly. Management practices to include closed-loop brine water storage and pipeline leak monitors and shutoff valves are recommended on wells close to the river to minimize the risk of a spill discharging into the river.

Petroleum hydrocarbons and volatile organic compounds (VOCs)—with some noted as carcinogens (benzene and xylene)—are toxic substances relative to water quality so the threat of petroleum pipeline spills and leaks can create extensive short- and long-term damage to aquatic life and other uses (World Health Organization 2014). Although not discussed in detail here, these products can also impact ground water via pipeline leaks and breaks. In addition to the impacts of hydrocarbons, a recent USGS study linked petroleum spills with elevated concentrations of arsenic in ground water (Cozzarelli 2015).

A number of VOC compounds have been detected in surface and ground water and sediment in the Yellowstone corridor, albeit at low levels (Peterson et al. 2004). At least one VOC was detected in 85 percent of wells sampled from Quaternary aquifers, primarily VOC compounds associated with gasoline. Other samples of sediment near Billings had concentrations of related PAH compounds that were high enough to pose a potential threat to aquatic life.

Natural gas and related materials pose less hazardous threats to aquatic life and human due to their relatively low solubility and propensity to volatize. Ignition is the primary hazard. Natural gas is not regulated by Montana or EPA as a water pollutant (MDEQ 2012a).

4.6.8 Agriculture: Impacts on Water Quality

Potential pollutants from agricultural sources include sediment, nutrients, salts, pathogens, and pesticides. Habitat alterations and agricultural runoff might also increase water temperature (MDEQ 2012b). Agricultural runoff and return flows are typically considered nonpoint sources. Agricultural point sources are regulated under the Clean Water Act (CWA) or the Montana Water Quality Act. Point sources discharging to waters of the U.S. or state waters within the Yellowstone River are discussed further in Section 4.6.10.1. Systematically implemented management practices are recommended to reduce water pollution related to agricultural nonpoint sources under Montana's Nonpoint Source Management Plan (MDEQ 2012b).

Depletion of streamflow can be a serious impact of irrigation on water quality. Irrigation withdrawal is listed as the second leading agricultural cause of non-attainment of beneficial uses in Montana (MDEQ 2012). Cumulative losses of water due to irrigation withdrawals described in Section 4.3 can affect summer low flows in the lower Yellowstone River to the point that the river's capacity to dilute pollutants and cool warmer return flows is diminished. Dilution capacity is important as the 7Q10 flow is used to calculate allowable discharges for MPDES permits under the CWA. Since the impact of some pollutants (e.g., toxins and bioaccumulated pollutants) is not affected by dilution, most classic indicators of water pollution benefit from additional solvent added to a known quantity of solute, or as the saying goes, "The solution to pollution is dilution." While not always true from a load standpoint, more water is better than less when it comes to evaluating the impacts of water quality pollutants.

4.6.8.1 Crop Production Runoff

Cropland runoff can carry salts, nutrients, bacteria, pesticides, and sediment in addition to altering water temperature. The USGS NAWQA program reports suggest that observed increases in dissolved solids, nutrients, pesticides, and sediment is due in part to agricultural sources within the basin (Miller et al. 2005). Not all of these sources are located within the corridor; in fact, most are located within tributaries far upstream from the Yellowstone River.

Closer to the river, irrigated crop production, particularly furrow irrigation used for row crop production (corn, beans, and sugar beets), has the potential to transport salt, sediment, nutrients, and pesticides in runoff unless good irrigation and farming practices are utilized. Sprinkler irrigation has the potential to apply water with less leaching and runoff; however, it is not suited to production of all crops nor to every producer. The Yellowstone SPARROW model indicated that the areas with the largest predicted contribution of delivered aggregated total nitrogen yield are most often located along the Yellowstone mainstem, with farm fertilizer as the greatest source (Frankforter et al. 2015, in review). Use of appropriate nutrient and irrigation water management recommended practices (see Section 8.1) as part of a comprehensive management approach can substantially reduce pollutant transport and delivery to the Yellowstone River.

Targeted conservation education, demonstration, and outreach are necessary to eliminate these sources of pollution in the future before they impair the many uses of the river. The reality is that the development and implementation of a suite of integrated management practices blending nutrient management, pesticide management, residue and tillage management, irrigation water management (where appropriate), and cropping systems is needed to significantly reduce cropland runoff. Practices designed to enhance soil health create many by-products that also reduce the quantity and improve the quality of agricultural runoff.

4.6.8.2 Animal Feeding Operations

Animal Feeding Operations (AFOs), by definition, are facilities where domestic livestock are confined, stabled, and fed for more than 45 days within a 12-month period resulting in a ground surface predominantly devoid of vegetation during the growing season or period of use (CFR, *Federal Register*, V. 68 No. 1, page 7265). Livestock producers in the Yellowstone Valley often feed livestock to add value to crops raised on the farm. AFOs have the potential to discharge sediment, nutrients, organic waste (oxygen-demanding substances), and waterborne pathogens to ground and surface waters (USEPA 2014b). They may also release ammonia, odors, and other airborne pollutants that enter waterways. AFOs are considered nonpoint sources. Certain AFO facilities may be defined or designated as a

Concentrated Animal Feeding Operation (CAFO) based on size and discharging to state waters. As point sources, CAFOs are regulated under the Montana Pollutant Discharge Elimination System (MPDES) and similar permits in North Dakota. Properly sited and managed to avoid frequent discharges, AFOs can operate without contributing pollutants to nearby waterways or groundwater resources.

The Yellowstone River land use inventory and analysis (DTM 2013) indicates that there are about 41 individual AFO operations on about 431 acres within the 100-year inundation boundary. These facilities are cattle-feeding operations for the most part. Figure 4-106 displays the relative distribution of mapped AFOs along the corridor. The vertical Y-axis shows both the number and size (acres) of the operations based on 2013 Land Use Mapping data. Most operations occur in the lower river where more corn and silage is grown and used for cattle feed. These sites range from very small to larger operations. Region C has the greatest number and spatial extent of AFOs containing about half of all AFOs in the inventory. Twenty-six feeding operations hold CAFO discharge permits within 1 mile of the Yellowstone River in Montana (MDEQ 2015a).

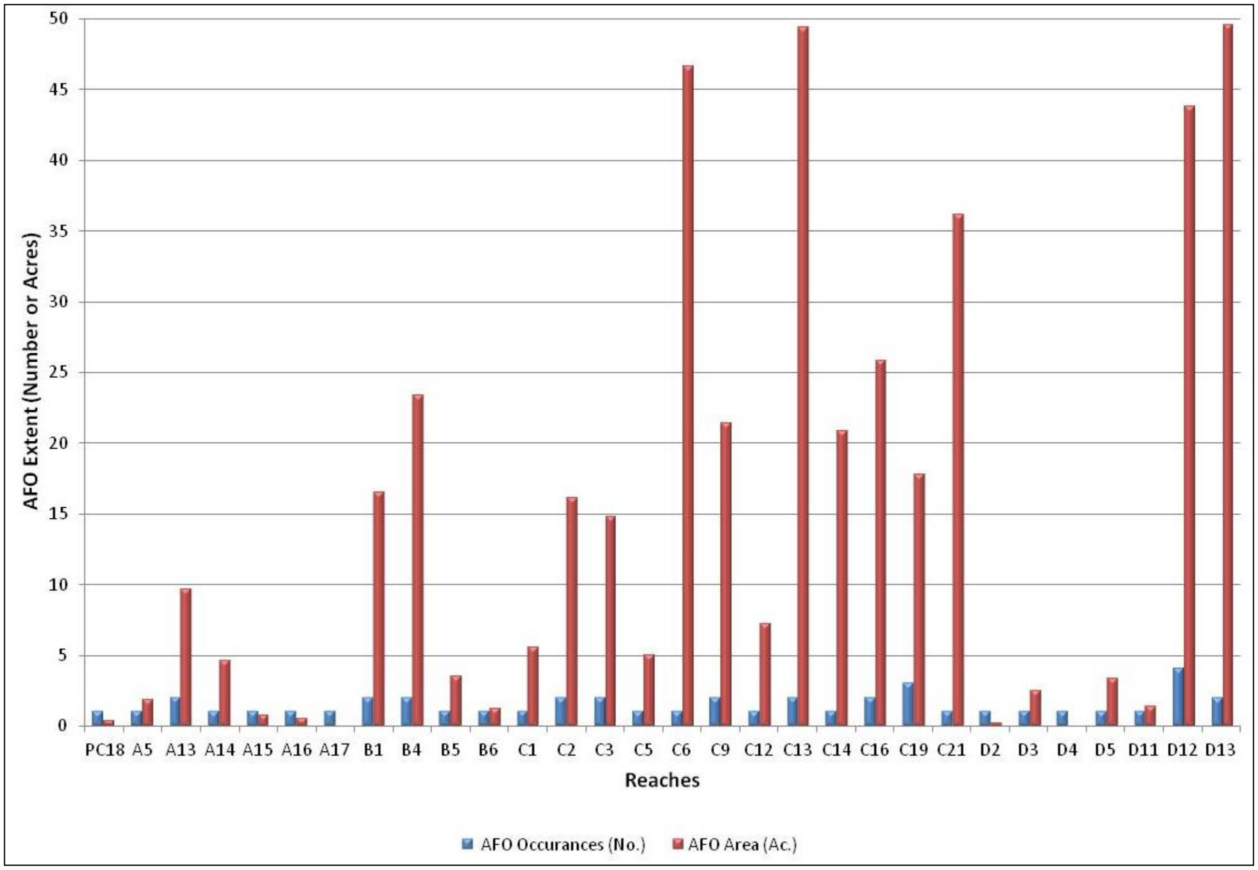


Figure 4-106 Animal feeding operations within geomorphic reaches within the 100-year inundation boundary along the Yellowstone River; Irrigation Withdrawals/Flow Depletion

There is no data to directly relate AFOs, individually or collectively, to water quality values measured in the Yellowstone River. Fecal coliform and *E. coli* bacteria occurred at the highest levels in urban and agricultural areas of the Yellowstone watershed, likely due to sewage treatment plants, agricultural livestock, domestic animals, wildlife waste, and septic systems; however, most of the bacteria colony exceedances occurred in tributaries and not in the Yellowstone River (Peterson et al. 2004).

4.6.8.3 Conversion of Riparian Habitat to Agriculture Land Use: Increased Runoff/Leaching from Agricultural Lands

Conversion of riparian land cover to more intensive agricultural uses such as irrigated crop, pasture, or hay land may result in an increased potential for nutrients, salts, and sediment to enter the river due to removal of the vegetative buffer (see Figure 4-107). Riparian and wetland cover provides a buffer zone for the attenuation of water pollutants (Klapproth and Johnson 2009; Lowrance et al. 1984; Parsons et al. 1994). Removal of riparian and wetland vegetation can provide accelerated pathways for these pollutants to enter the river (Ranalli and Macalady 2010). Nutrients and salts are the primary pollutants of concern but pesticides are also important since many have been detected in surface and ground water in the Yellowstone River corridor (Miller et al. 2005; Peterson et al. 2004; Mulder and Schmidt 2011).

Figure 4-107 Riparian buffer along left river bank protects adjacent cropland while narrow to no buffer on the right bank leaves cropland vulnerable to erosion and flood debris damage

The extent of riparian conversions to agricultural land is discussed in Section 4.2 (Land Use Change) and Section 4.7 (Biology: Terrestrial Plants (Riparian Systems)) and their associated appendices. Restoration of riparian and palustrine wetland habitats in areas where they have been removed or their function altered can be used to reduce pollutant delivery and nutrient loads draining to the Yellowstone River. Protection of effective riparian habitat and processes that sustain riparian recruitment should be an objective of ongoing river management to protect water quality in reaches where agricultural lands adjoin the river.

4.6.8.4 Habitat Alteration Impacts on Water Quality: Grazing

Uncontrolled or unmanaged livestock grazing can degrade the integrity and function of riparian and floodplain habitats, thereby increasing the potential for pollutants to enter waterways. Nutrients, sediment, organic matter, and pathogens are the pollutants of concern associated with livestock grazing. As noted in Section 4.7 Riparian, livestock grazing can simplify riparian habitats by removing biomass, reducing woody cover, leaving banks physically trampled, and removing understory vegetation resulting in loss of riparian function to trap and sequester pollutants (Belksy et al. 1999).

Livestock grazing in riparian and shoreline zones is listed as the leading agricultural cause of beneficial use non-attainment in Montana affecting over 115 assessment units (MDEQ 2012b). Smith et al. (1997) estimated that fertilizer and manure contributed 45 percent of the phosphorus to the Clarks Fork of the Yellowstone River. The Yellowstone SPARROW model predicted that animal manure is responsible for 22 percent of total phosphorus yield in the basin (Frankforter et. al. 2015, in review). Prescribed grazing practices can focus the timing, duration, frequency, and intensity of livestock use in a manner that results in protection of riparian vegetation composition, diversity, and residual cover—which helps to maintain water quality and other important functions, and are particularly recommended for use within the Yellowstone River Corridor.

4.6.9 Urban/Exurban Development: Impacts on Water Quality

As land use intensifies and urban/exurban development occupies more and more of the watershed and near-channel landscape, there is greater potential for water quality to be adversely affected. This situation is primarily due to on- and off-site waste and sewage disposal/treatment and a concurrent decrease in the capacity of the landscape to infiltrate precipitation as impervious surfaces increase. The main areas of concern are related to nutrients, pesticides, pathogens, and sediment.

4.6.9.1 Conversion of Riparian and Wetland Habitat to Urban/Exurban Development: Increased Runoff, Pesticides, and Nutrients

Sections 4.7 (Terrestrial Plants) and 4.8 (Aquatic Plants) and their associated appendices discuss the extent to which riparian habitat was converted to urban-exurban development between 1950 and 2011 within regions A–D. The analysis is not available for the PC Region. Additional detail concerning conversion of riparian habitat to urban/exurban development is found in Section 4.2 (Land Use). The extent to which these changes have occurred in reaches B1–B3 (the Billings metro area), C17 (the Miles City area), and D6 (the Glendive area) shown in Table 4-13, indicates that the conversion is closely related to their proximity to large urban areas. Substantially less riparian habitat conversion is noted in areas closer to smaller communities along the corridor (not depicted).

Table 4-13
Percent Conversion of Riparian Cover in 1950 to Urban-Exurban Land Use in 2011

Reach B1	Reach B2	Reach B3	Reach C17	Reach D6
5%	50%	17%	18%	9%

Conversion of riparian cover to urban and exurban development can increase the potential for pollutants to enter waterways for largely the same reasons as for agricultural conversions. Urban and exurban areas typically have higher proportions of impervious surfaces associated with roads, streets, parking lots, and roofs, which alters the amount and timing of runoff. While the relative size of the Yellowstone River renders it somewhat less sensitive to the impacts of impervious surfaces, large towns like Billings, Miles City, and Sidney can impact the river locally through altered rates of runoff and discharged pollutants.

Nutrient enrichment, hydrocarbons, and pesticides have been detected in water, fish tissue, and sediment in river segments downstream of the Clarks Fork near Billings. Municipal wastewater treatment plants (WWTPs) and on-site sewage disposal systems have the potential to discharge excess nutrients and pathogens if not operated effectively. Typically, surface discharges to state waters from point sources like WWTPs are authorized through MPDES permits. Five WWTPs are major dischargers with individual permits (e.g., Billings, Glendive, Livingston, Miles City, and Sidney) (MDEQ 2014c). The USGS report by Peterson et al. (2004) also noted that WWTPs along the river have continued to improve their technology and performance in removing sewage waterborne pollutants, particularly nutrients, chlorides, and fecal coliform bacteria, thereby greatly improving water quality indicators over those observed in the Yellowstone River in the 1950s (Bahls 1976; Karich and Thomas 1977). The Yellowstone SPARROW model predicted that 5 percent of the total phosphorus delivered in the river is due to WWTPs. Of greater influence, the model predicted that in 2002 in the Upper Yellowstone-Pompeys Pillar HUC8, WWTPs contributed nearly 40 percent of total nitrogen yield, although recent upgrades could have further reduced this proportion (Frankforter et. al. 2015, in review).

Poorly designed or neglected septic disposal systems can be sources of excess nutrients and pathogens. Standard design septic systems do not effectively remove nitrate and, therefore, contribute to elevated concentrations of nitrate in ground water (MDEQ 2012). Elevated levels of nitrate were found in ground and surface water draining developments in the Billings area by Mulder and Schmidt (2011). The use of appropriate recommended practices to design, install, and maintain approved septic systems is needed to eliminate excess pollutants entering surface waters via ground water return flow.

While it is not known how many septic systems are located within the Yellowstone River corridor at any one point in time, a septic tank density tool was developed by the Montana Natural Resource Information System (NRIS) to allow estimation of septic system density risk factors along Montana's waterways (2015). Data was not available for reaches D15 and D16 in North Dakota. Figure 4-108 depicts river reaches where change between 1990 and 2010 was in excess of 0.2 acres per valley mile.

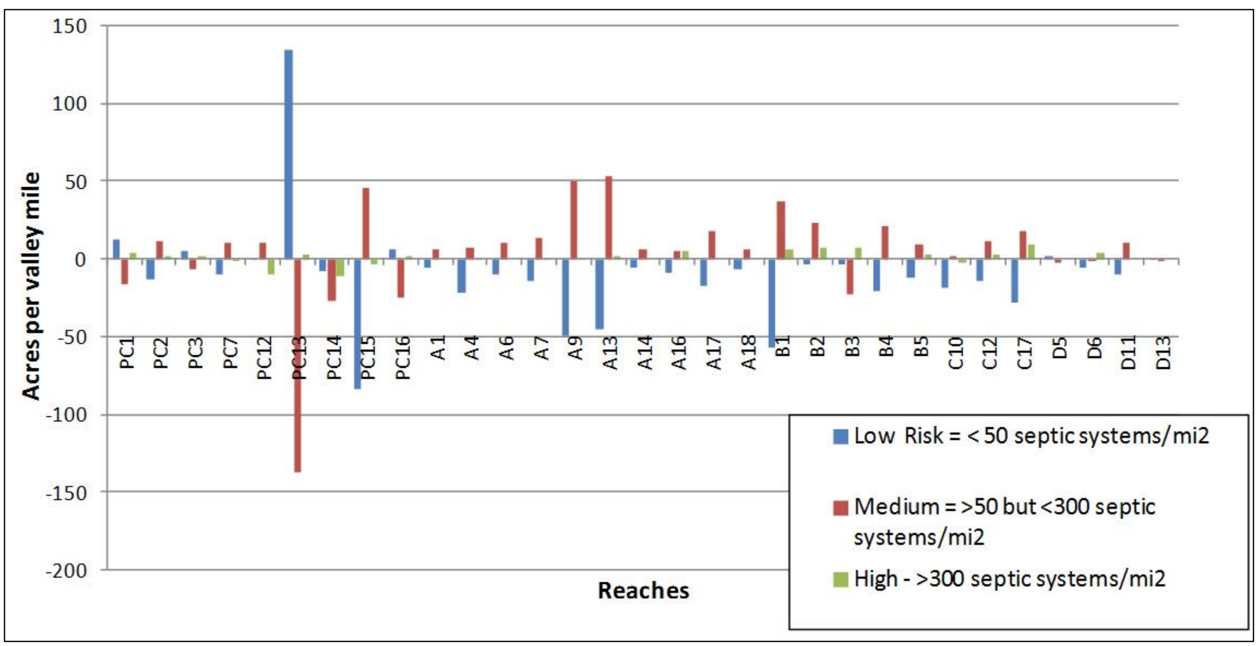


Figure 4-108 Change from 1990 to 2010 in acreages (per valley mile) of estimated septic tank density risk ratings that occurred within CEA reaches

In Park County (the PC reaches), densities are the highest in Reach PC13 (Carters Bridge to Interstate and PC15, Mayor's Landing area). Other areas with elevated risk ratings are A9 and A13, Reed Point and Columbus, respectively. B2 is in the Billings area. Smaller but regular changes are seen going downstream near existing communities. Losses in acreage generally represent a shift from low risk to medium or high, although in some cases lower population in 2010 led to decreases in risk value and acreage. Reaches not shown in the chart had very low to no change evident in risk ratings between 1999 and 2010.

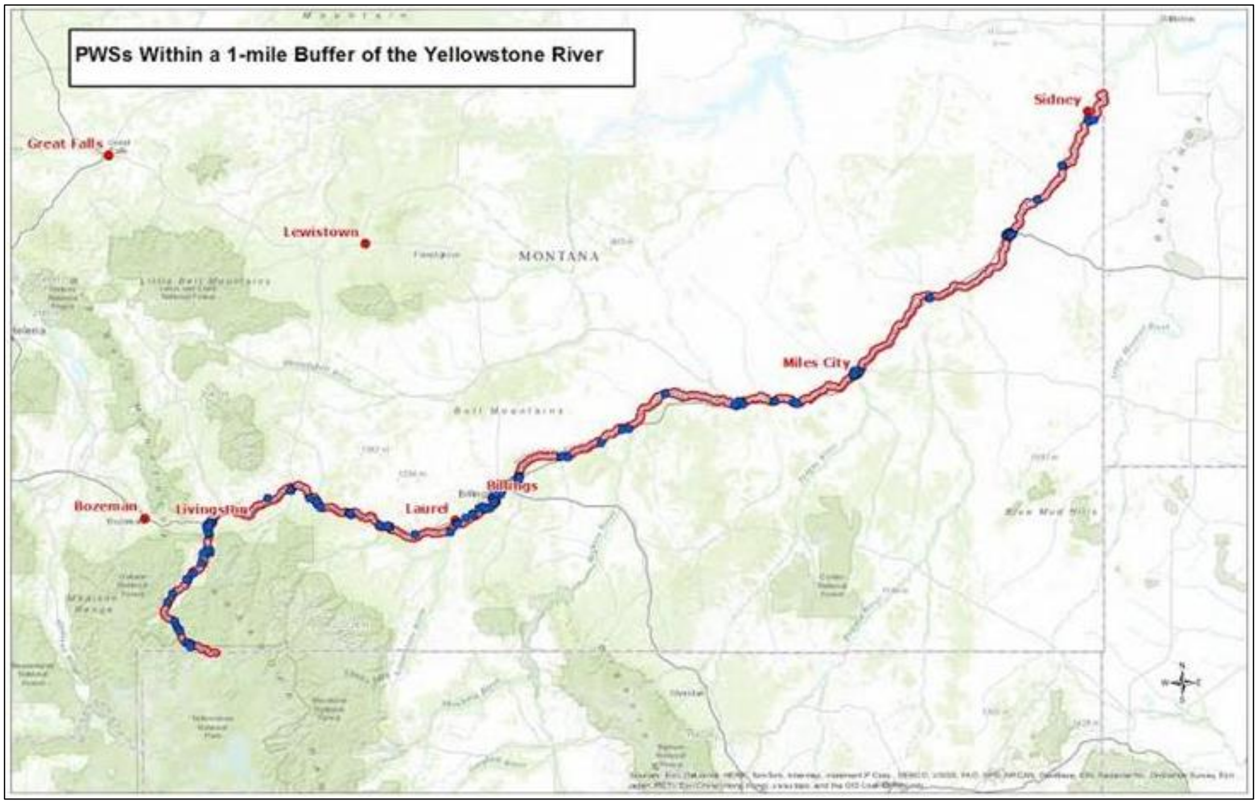
In terms of risk category acreage, Region B had the most 2010 acreage in the medium risk and high risk categories as a result of population growth and number of farms (2,122 acres and 364 acres, respectively). The Park County (PC) Region is not far behind given the expansion of rural/exurban developments over the past 20 years (with 1,178 acres and 238 acres, respectively). Low risk acreage basically represents the area of the 1-mile wide corridor that is not either medium or high risk.

Landfills can pose a threat to water quality as harmful and toxic substances can leach into shallow ground water aquifers or surface waters. Older, unlined landfills pose a greater threat. Waterborne pollutants from land disposal include nutrients, pathogens, pharmaceutical compounds, and personal care products (National Association of Clean Water Agencies 2005). Landfills are regulated by the MDEQ. At least three currently operating landfill facilities are located within 1 mile of the Yellowstone River corridor. The landfill database at the Natural Resource Information System's (NRIS) Digital Atlas of Montana (2015) shows there are five closed facilities within one-half mile of the river: Big Timber, Columbus, Custer, Forsyth, and Lockwood. Additionally, there is an old closed facility adjacent to the river near Livingston that is not included in the database (T. Pick, personal observation).

Stormwater runoff from urban and exurban areas, particularly during construction, can carry sediment and other pollutants at orders of magnitude higher than background levels. Sediment yields from construction site runoff can be 1,000 times greater than from forestland (Owen 1975).

Over 260 MPDES stormwater permits are currently in place for construction activities within one mile of the Yellowstone River in Montana (MDEQ 2014c), 65 of which were issued for subdivision and exurban development. In the Yellowstone River corridor, pollution from stormwater runoff is relatively localized because the number and scale of urban areas is limited. Point-source discharge permits for municipal storm sewer systems are currently required for seven urban areas in Montana, however only one system is located within the Yellowstone River watershed, Billings. Additionally, portions of Yellowstone County and Montana Department of Transportation facilities (within the designated urban areas that require permits) hold discharge permits. Constructed or restored wetlands can be used to capture and treat surface and ground water flow to remove nutrients (Collins and Gillies 2014; Harrison et al. 2014). Similarly, low impact development (LID) practices can be used to contain pollutants and reduce the temperature of stormwater runoff (Long and Dymond 2014).

Figure 4-109 shows the location of over 80 public water supply (PWS) systems within 1 mile of the Yellowstone River in Montana (MDEQ 2014b). Eight of the systems, including seven communities, draw and treat surface water from the Yellowstone River to serve about 145,000 people. The source of the other systems is ground water within the river corridor. Data for North Dakota was not available. These PWS systems serve nearly 165,000 people using ground and surface water sources. The communities of Billings, Forsyth, Glendive, Hysham, Laurel, Lockwood, and Miles City serve about 90 percent of that population and depend on surface water quality and quantity to meet their residents water needs (MDEQ 2014b). Low flows have affected public water supplies drawing on surface water in drought years in the Billings area. Suspended sediment, algal residue, pathogens, TDS, metals, and alkalinity have the greatest impact on water quality treatment by increasing treatment costs.



Source: MDEQ, Water Protection Bureau, Helena, MT

Figure 4-109 Map of the more than 80 public water supply (PWS) (blue dots) systems within 1 mile of the Yellowstone River in Montana

Note: *Urban and exurban development requires adequate sources of high quality water to serve residents and businesses.*

4.6.10 Industrial Development: Impacts on Water Quality

4.6.10.1 Industrial Wastewater Discharge: Surface and Ground Water Pollution from Return Flows

Wastewater discharges potentially add pollutants to the Yellowstone River. Industrial discharges can potentially affect water quality by contributing manufacturing or processing waste products such as ammonia, SVOCs, PAHs, solvents, nutrients, chlorides, sulfates, metals, grease, and other pollutants. Eight MPDES-permitted industrial facilities discharge process wastewater to the Yellowstone River following treatment (MDEQ 2014c).

Effluent limits are placed on the appropriate effluent parameter; however, permits often provide for a mixing zone below the permitted outfall. The size of the mixing zone is dependent on the nature of the discharge and its constituents, and the quality and quantity of the receiving water.

Industrial discharges can often require cooling before discharge in order to meet state water quality temperature standards applicable to the classification of the receiving water. All MPDES permits require water quality monitoring and compliance reporting to ensure conformity with effluent limitations specified in the individual permits.

The application, Mapping MDEQ's Data (MDEQ 2015b), has a total of 27 gravel pits located within about one-half mile of the Yellowstone River. Gravel pits can be required to obtain and follow a MPDES stormwater discharge permit if they discharge to state water (MDEQ 2013). Operators following approved surface mining management practices and properly reclaiming disturbed ground, however, generally are not a risk to water quality.

4.6.10.2 Industrial Water Use: Water Withdrawals/Flow Depletion

As discussed previously, increased water depletions in the Yellowstone River that diminish discharge have the potential to affect the assimilative capacity of the river in diluting and degrading pollutants. Industrial water use is relatively minor compared to irrigated agriculture's use of water. Thermoelectric power plants are the second highest users of Yellowstone River Basin water.

Coal mining uses relatively less water than power production. If additional proposed coal mines and production facilities are built that result in increased water use and consumption, they may impact the lower river's capacity to meet demand and not impair uses in July, August, September, and October (Montana Department of Natural Resources and Conservation 1977; Klarich and Thomas 1981).

Coal-bed natural gas requires the pumping of ground water as part of the production process. Coal-bed natural gas production water typically has elevated TDS and sodium adsorption ratio levels (Clark 2012; Clark and Mason 2006), which can have detrimental impacts on soil and crops. Discharging coal-bed natural gas wells in Montana requires a MPDES permit that sets effluent limits for the pertinent constituents. Relatively few MPDES permits are currently in place in the Powder River Basin in Montana. No coal-bed natural gas wells currently discharge directly into the Yellowstone River. Existing Montana coal-bed natural gas wells discharge into the Tongue River. In Wyoming, large numbers of coal-bed natural gas wells discharge into the Powder and Tongue Rivers, although recent studies have shown some weak statistical trends in major ions over time (Sando et al. 2014).

The recent expansion of oil and natural gas drilling and production into the lower Yellowstone River corridor near Glendive and Sidney as part of resource extraction activity in the Bakken and Williston Basin in North Dakota and Montana creates additional demand for water resources. The hydraulic fracturing process—or "fracking"—used to enhance extraction of natural gas and oil from shale formations requires abundant water resources. Several million gallons of water are used per well. Alternate technologies are being tested to use air pressure, CO_2, or other inert materials for this purpose but at present, water is the most effective and economical medium. Once used and extracted, the water is contaminated with drilling materials and is typically deep injected to dispose of it. As this water is not directly returned to the drainage from which it is removed, the process constitutes a consumptive use. Should extensive oil and gas development continue in the lower Yellowstone River, this industrial use could result in substantial water consumption relative to other uses.

In summary, industrial-related activities that lead to increased consumption of Yellowstone River water in the future could affect late season flows in the middle and lower river and concentrate pollutants that negatively affect aquatic life and other beneficial uses. Water conservation practices and reuse technologies can help to reduce the impact of future water demand on Yellowstone River resources.

4.6.11 Invasive Species: Impacts on Water Quality

Invasive species are primarily a threat to the species composition, structure, and health of native vegetation in uplands, wetlands, and riparian habitat adjacent to the river, as discussed in Sections 4.7 and 4.8. A few invasive plant species also have the potential to impact water quality because of the water-soluble compounds they contain. Russian olive (*Elaeagnus angustifolia*) and saltcedar (*Tamarix* spp.) are two invasive species that have been shown to affect water quality.

4.6.11.1 Russian Olive and Saltcedar

Russian olive has been found to affect water quality in several ways. Research shows that the plant's roots are associated with a nitrogen-fixing bacteria that accumulates nitrogen in the soil (Mineau et al. 2011). Dense Russian olive stands adjacent to streams contribute nitrogen to surface and ground water. The added nitrogen can alter biochemical cycling in the receiving water, causing a chain reaction of impacts to aquatic organisms ranging from biofilms to fish. Secondarily, the increased organic load added by Russian olive leaves and fruits in surface water can increase the biological oxygen demand and reduce DO levels. A study underway in Idaho suggests that the increased food source provided by Russian olive leaves and fruits may favor the growth of exotic aquatic species like common carp (O'Connell 2014).

Saltcedar plants have been shown to accumulate salts (sodium, calcium, and magnesium) and metals (lead and cadmium) in their leaves and exude these elements on the leaf surface (Kadukova et al. 2008). The elements are then shed with the leaf and collect at the ground surface where they can affect water quality and native riparian species germination (Jacobs and Sing 2007). In the southwestern U.S., a single saltcedar plant has been reported to transpire as much as 200 gallons of water per day but this does not seem to be the case within the Yellowstone basin in Montana (Meredith and Wheaton 2011), so impacts on the quantity of water resources may not be so severe in a northern climate.

4.6.11.2 Aquatic Invasive Species

A number of aquatic invasive species have the potential to affect water quality by altering the amount of organic material that is added and decomposed in the river. Growth of dense masses of submerged and emergent invasive aquatic species are benefited by elevated nutrients in water. These species can reduce streamflow and alter DO levels and water temperature (see Appendix 6 (Terrestrial Plants (Riparian Systems)) for additional information). The added load of decomposing organic materials created by invasive species can then tie up DO, harming aquatic life. Floating single-celled algae and phytoplankton can increase the turbidity of water. Some invasive species such as zebra mussels (*Dreissena polymorpha*) can alter water clarity and the nutrient balance (turbidity) through the process of filtration. In any case, invasive species by nature reset chemical, physical, and biological thresholds in their environment, thereby creating a new "normal" for an ecosystem.

In summary, invasive species have the potential to alter water quality of the Yellowstone River through both chemical, physical, and biological processes. Added emphasis on the role and threat posed by present and future invasive species will help to ensure that these potential threats do not become reality in the Yellowstone River Basin.

4.6.12 Off Corridor Impacts

4.6.12.1 Yellowtail Dam: Altered Hydrograph, Stream Morphology, Water Temperature, and Sediment

Major impacts of the Bighorn River on the hydrology of the lower Yellowstone River have been discussed throughout many of the Cumulative Effects Analysis (CEA) sections. A few additional points relative to Yellowtail Dam are worth mentioning in terms of water quality impacts:

- The Bighorn River is a low-sodium, high-salinity water and presents some hazards for irrigators using the water (Soltero et al. 1973). Because of the operation of the dam in regulating flows, the water is diluted sufficiently that it does not impact the water quality of the Yellowstone River below the confluence during summer months when irrigation is taking place. Should upstream water withdrawals in the Yellowstone increase—resulting in diminished summer discharge below the Bighorn—there is the potential for TDS in the Yellowstone to be measurably affected during low-flow periods.

- Yellowtail Dam discharges water that is cooler than natural conditions. This discharge supports a Blue Ribbon coldwater trout fishery below the dam. Summer water temperatures below the mouth of the Bighorn do not seem to be appreciably affected by this coldwater discharge. Anecdotally, winter water temperatures in the Yellowstone River below the confluence and as far downstream as Forsyth are thought to be warmed by Bighorn River water inflow. Data and studies analyzing the possible impacts of this potential effect are lacking, however.

- Mercury accumulation in fish and gas bubble trauma in trout are known Bighorn River issues. While gas bubble trauma is not carried downstream into the Yellowstone River, since mercury testing in fish has not occurred in the Yellowstone River below the Bighorn confluence, the extent that it carries into the Yellowstone is unknown.

- Sediment retention in Bighorn Reservoir has been previously addressed in this document. Reduction of the sediment load delivered to the Yellowstone River is thought to adversely affect the habitat requirements of some fish species, specifically sauger (*Sander canadensis*) (Jaeger 2004).

4.6.12.2 Climate Change

Specific climate projections and analyses have not been made as part of the Yellowstone Cumulative Effects Analysis because of limitations in time and resources but are encouraged to be undertaken as resources are available by those who follow this work. Following are the major points emphasized in a review of pertinent climate change research and peer-reviewed literature:

- Climate change can potentially impact water quality in the Yellowstone River and its tributaries through a number of climate-related mechanisms altering the timing, distribution, and volume of stream discharge (Chang and Hansen 2014; Montana DNRC 2015); Leppi et al. 2011; Stewart et al. 2004; Mote 2003; IPCC 1998).

- Long-term climate indicators show that a much drier climate might have better represented conditions in the previous millennia in the Yellowstone watershed (Graumlich et al. 2003). In the northern Great Plains area, which encompasses the Yellowstone River Basin, total precipitation decreased by 10–20 percent since1990 (IPCC 1998). Even though precipitation in the higher elevation greater Yellowstone region has increased slightly the past three decades, aridity has increased due to temperature increases. Snowpack over the past 50 years is now about only 20 percent of the 800-year average in the greater Yellowstone region. Temperatures are expected to continue to rise 3.0 to 7.0^{0}C over the next century under some of the climate projections (Chang and Hansen 2014).

- Warmer air and water temperatures coupled with reduced streamflow can be expected to negatively affect water quality in the Yellowstone River Basin (Miller 2008; Montana DNRC 2015)). Changes in the timing and duration of spring runoff, noted earlier in this report, can also be expected to adversely impact water quality and aquatic species.

Decreased flows during past drought periods have lessened the diluting effect of streams on pollutants. For example, substantial increases in nitrate nitrogen (NO_3-N) concentrations were noted during drought years (2000–2001) due to less dilution of nitrate-rich ground water discharges (Miller 1999). Lower DO levels and higher stream temperatures also might occur during extended periods of low flows, adversely affecting aquatic life (Matthai 1979; Miller 2008). Similar or even greater pollutant concentrations can be expected in a more arid climate when demand for water resources in the Yellowstone River might be heightened.

Invasive species might be favored by a warming climate. As the impact of invasive species can alter the function of riparian and wetland habitats (Section 4.7), the capacity of these areas to trap and sequester pollutants will decline with the potential to increase pollutant loads from adjacent exurban and agricultural land. Reduction in the extent and function of riparian and wetland habitat, whether through the impact of invasive species or conversion to other uses, will diminish these functions and negatively affect water quality.

The impacts of climate change on water quality in the Yellowstone River Basin could vary for upper and lower segments of the river due to differences in elevation, precipitation, air temperature, and land cover and use, and the contribution of return flows from irrigation. The recommended approach to most successfully accommodating the impacts of climate change is adaptive management using effective monitoring, flexibility, and collaborative planning to protect water quality and quantity in the basin (Montana DNRC 2015).

4.7 Biology: Terrestrial Plants (Riparian Systems)

4.7.1 Introduction

Riparian plant communities within the Yellowstone River corridor are located adjacent to the channels (or other waterways) where the vegetation is influenced by the presence of surface and sub-surface free water. Riparian vegetation is distinctly different from and is transitional between the wetter aquatic ecosystem in the channel and the adjacent but drier uplands. Riparian areas can include some components of jurisdictional wetlands protected under Section 404 of the Clean Water Act (CWA; 33 U.S.C.), but by definition, they are not always considered wetlands (National Academy of Science 2002). Within the Cumulative Effects Analysis (CEA), riparian systems will be considered separately from wetland systems (Section 4.8).

The scope and character of a riparian area is directly related to the hydrologic characteristics and geologic setting. The fluvial processes of streamflow (flooding) and sediment erosion and deposition drive the dynamics of the riparian disturbance regime. Channel migration is the primary mechanism that both provides fresh substrate for renewal (deposition) and removes established riparian habitat and soil (erosion). A dynamic equilibrium exists where there is a balance between the two processes.

Potential riparian vegetation may consist of herbaceous plants only or a combination of herbaceous and woody species progressing through a gradient of age and/or density-related vegetative classes, beginning as closely spaced seedlings and growing through a closed (canopy) timber stage with or without a shrub understory (Boggs 1984; Eggers 2005). As the age class matures, the typical stand then transitions to a mature, openly spaced timber stand before the trees eventually senesce and die. The site then transitions to an upland grass/shrub complex, which may no longer be considered a riparian community type if the free water that the migrating channel initially provided is unavailable. A riparian forest may persist in the absence of disturbance on sites where soil moisture is abundant. In places, excessively wet soils without adequate oxygenation may persist as herbaceous-dominated riparian communities (Hansen et al. 1995).

Riparian areas are a relatively small component of the total land cover in the arid west and, for this reason, provide disproportionally distinctive environmental services (Ellis 2008; Belsky et al. 1999; Braatne et al. 1996). Studies conducted by the Governor's Upper Yellowstone Task Force determined that riparian woodlands represented less than 1 percent of the Upper Yellowstone watershed land cover (Pick and Potter 2003). Riparian areas are noted to provide thermal regulation, provide wildlife habitat diversity and food, filter and transform pollutants, attenuate and store floodwaters and sediment, and stabilize streambanks (NAS 2002; Brinson et al. 1981). They also provide many forms of recreational and economic activity in the form of livestock grazing, wildlife viewing, hunting, and fishing opportunities.

Because of the availability of water and generally deeper alluvial soils, riparian areas are generally much more productive proportionally than adjacent uplands. Riparian areas in Montana support at least 56 percent of all Montana's mammal species seasonally or year-round. Sixteen native amphibians, three species of turtles, and seven snake species use streamside buffers and wetlands. Fifty-five percent of 245 breeding avian species use riparian forests (Skagen et al. 2001; Ellis 2008). For these reasons and those previously mentioned, riparian areas represent extremely valuable and important components of the western landscape and are a major source of the economic and environmental values associated with the Yellowstone River ecosystem.

Riparian vegetation, as noted, is intrinsically tied to waterways and floodplains where humans have made extensive investment on these fertile, productive lands. Numerous case studies show that riparian areas are among the most severely altered landscapes in the country (Brinson et al. 1981; Elmore and Kauffman 1994). Losses of the historical riparian habitat in the western U.S. may be as much as 66–95 percent (Swift 1984; Krueper 1993). Human alteration of riparian communities spans a wide range of vectors from altering the hydrology of rivers and lakes to geomorphic manipulation to direct removal of vegetation for transportation corridors, development, agriculture, and timber harvest (NAS 2002; Elmore 1996). Mining, while active in the headwaters of some tributaries, has not had a significant impact on the riparian resource in the Yellowstone River CEA project area.

Riparian plant communities in the upper Yellowstone corridor (regions PC and A) typically consist of narrowleaf cottonwood (*Populus angustifolia*) with western snowberry (*Symphoricarpos occidentalis*) or red-osier dogwood (*Cornus sericea*) understory (Hansen et al. 2003). Black cottonwood (*Populus balsamifera ssp. tricocarpa*) is found in upper tributaries. Finer soils and near-shore sand bars are often colonized by sandbar (coyote) willow (*Salix exigua;* see Figure 4-110). Rocky Mountain juniper (*Juniperus scopulorum*) is the most common conifer in the riverine floodplain and occurs where coarse soils are well drained and riparian turnover rates are low. Narrowleaf cottonwood is the most common deciduous riparian forest tree down to the vicinity of Columbus (Eggers 2005; Jones 2001). Regions B, C, and D typically have similar riparian plant communities except for the fact that Great Plains cottonwood (*Populus deltoides*) replaces narrowleaf cottonwood as the dominant large tree (see Figure 4-111 and Figure 4-112). The two species sometimes produce a hybrid where they overlap.

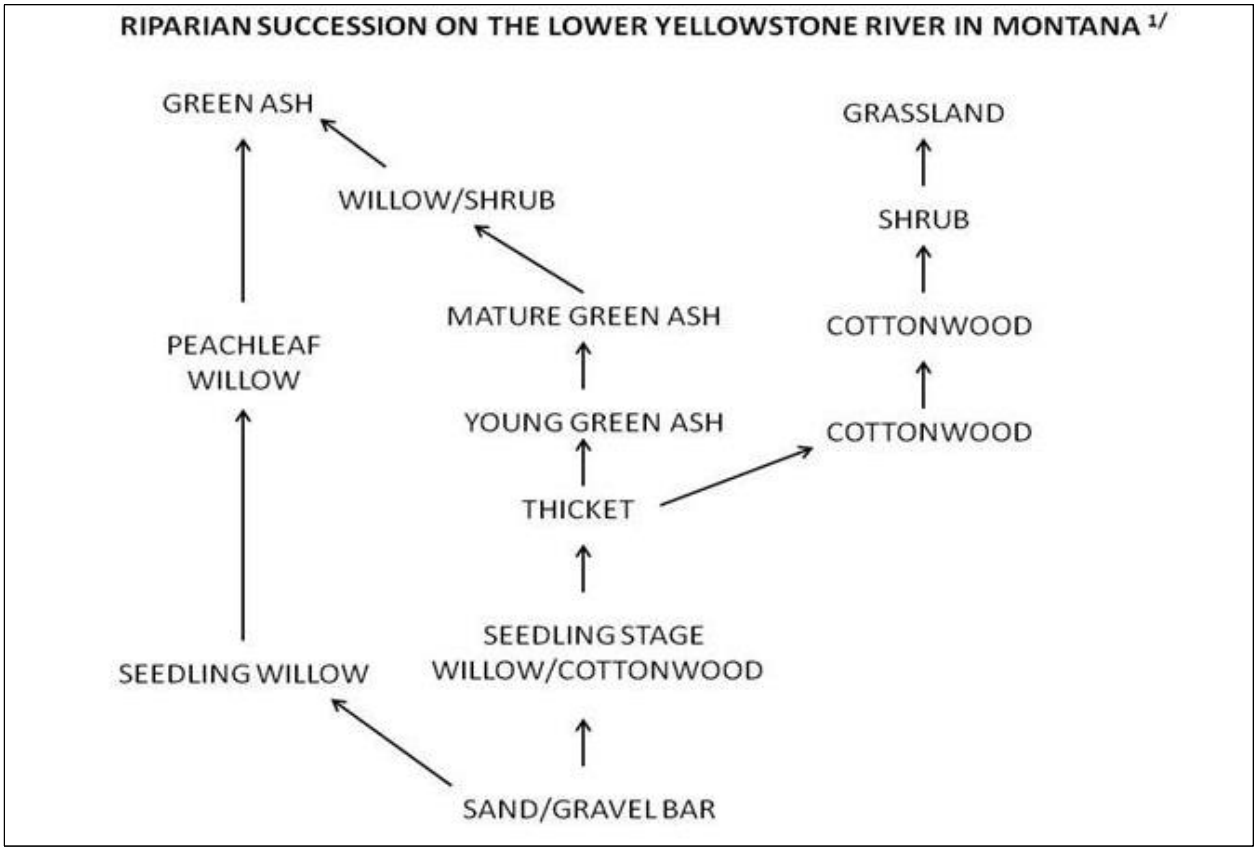
Peachleaf willow (Sal*ix amygdaloides*) is the most common tree-form willow in the upper portion, occurring in abandoned channels and oxbow areas. Yellow willow (*Salix lutea*) occurs more frequently in the lower river's floodplain, replacing peachleaf willow. In the late seral stage of this community type, barring disturbance or stand elimination, either juniper, green ash (*Fraxinus pennsylvanica;* see Figure 4-113), or box elder (*Acer negundo*) becomes the dominant woody species along with various wetland or upland herbaceous species depending on the moisture regime present (Hansen et al. 2005; Boggs 1984). Figure 4-114 illustrates various stages of vegetative succession in lower Yellowstone River riparian communities observed by Boggs (1984).

Figure 4-110 Plains cottonwood and sandbar willow seedlings carpeting freshly deposited sediment

Figure 4-111 Mosaic of Plains cottonwood forest in Reach D11
Note: *Younger closed timber (TC) in background with mature/decadent open timber (TO) in foreground transitioning to herbaceous shrub/grasslands*

Figure 4-112 Root mass of a Plains cottonwood forest
Note: *The extensive root mass provides extra physical strength and added resistance to bank erosion and flood energy compared to more shallow-rooted introduced grasses (especially in younger age classes)*

Figure 4-113 Green ash saplings growing in the shade of Plains cottonwood trees in Reach D10
Note: *With adequate moisture and proximity to groundwater, the green ash may eventually replace the cottonwood stand*



Source: Adapted from Boggs (1988)

Figure 4-114 General changes in dominant woody species communities in the lower Yellowstone River

This section describes human influences affecting terrestrial plant communities, specifically riparian systems within the Yellowstone River corridor: land use change, off-corridor impacts, hydrologic alteration, floodplain isolation, channel migration restriction, agriculture, urban/exurban development, and invasive species (see Table 4-14 for a summary of the primary human impacts identified as components of the riparian systems analysis). Note that the 100-year inundation zone (floodplain) used to describe and quantify impacts to riparian cover is not equivalent to the regulatory, 100-year floodplain or flood-prone area, or the area of the regulated/unregulated 100-year flow statistics described in Section 4.3.2.1. The 100-year inundation zone used here and in the wetland chapter is the area inundated by a 100-year flood without regard to dikes and levees in the floodplain. It was developed to assist with the Cumulative Effects Analysis (CEA) prior to when the later hydraulic and hydrologic analyses were completed by the US Army Corps of Engineers and USGS (Corps of Engineers 2011; Chase 2013, 2014).

Appendix 6 (Terrestrial Plants (Riparian Systems)) contains a summary of the supporting documentation for the riparian systems discussion with the Yellowstone River CEA. Spatial and temporal alterations to riparian systems, as well as the extent and magnitude of those impacts are described, as appropriate, along with analysis and discussion of the potential sources of those changes.

Most available references and studies used in this analysis are quantitative, but little information is available relative to qualitative studies excepting the vegetative community structure and dynamics studied by Boggs (1984) and Eggers (2005). Further studies are encouraged to measure the current status and future trend in condition or health of riparian areas within the Yellowstone River corridor.

Table 4-14
Summary of Human Impacts on Yellowstone River Riparian Systems

Human Influence	Impact on Riparian Systems	Spatial Extent	Relative Riparian Impact
Land Use Change	Conversion to other land uses	System-wide	Major
Off Corridor Impacts: Altered Hydrology on Bighorn River (Yellowtail Dam)	Reduced peak flows affect riparian energy regime	Below Bighorn	Major
	Reduced summer low flows alter local water table making riparian cover more susceptible to invasive species	Below Bighorn	Major
	Reduced channel forming/changing flows lower riparian recruitment and simplify wetland age and gender diversity over time	Below Bighorn	Major
Floodplain Isolation due to fills, dikes and levees.	Isolation of riparian habitat from channel and floodplain	Limited extent system-wide, but more pronounced in specific reaches	Moderate
Channel Restrictions due to bank stabilization activities	Long-term reduced channel migration and riparian recruitment leading to less age and gender diversity	Limited extent system-wide, but more pronounced in specific reaches	Locally major
Agriculture – Livestock Management	Simplification of habitat and possible nutrient enrichment/facilitate invasion by exotic species	System-wide	Moderate to major depending on management level
Invasive Species	Alteration of structure and species composition in riparian communities affects function and values	System-wide	Major
Climate Trends	Potential for reduced August low flows and increased evapotranspiration may make riparian habitat more vulnerable to invasive species and reduce opportunity for successful recruitment	System-wide	Uncertain but if recent trends continue, the impact is rated slight in the short-term and moderate in the long-term.
Municipal/Industrial Water Use	Potential for reduced low flows	Near urban and resource development	Uncertain, dependent on growth
Urban/Exurban Development	Potential for increased development pressure with population growth	Near population centers	Uncertain, dependent on growth
Change in Water Quality	Potential impacts to riparian recruitment and vegetative community composition	Mid-to-lower river	Uncertain, dependent on growth and future hydrologic modifications

4.7.2 Summary of Findings

The primary findings of the riparian analysis include the following:

- Much of the extensive cottonwood forests reported by early day explorers in broad valley areas along the Yellowstone River no longer exist, having been harvested or cleared and converted to other land uses prior to 1950. As of 2001, riparian extent makes up about 21 percent of the 100-year inundation area (DTM and AGI 2008a); extent is strongly related to geomorphic reach type with more extent in less confined reaches.

- System-wide, there has been little net change in riparian extent between 1950 and 2001. Some individual reaches, however, have experienced significant change. For example:

  - Over 5,500 acres of 1950s riparian cover were converted to irrigated agricultural land uses by 2011 with 2,900 acres converted in Region D alone.
  - Over 1,100 riparian acres were converted to urban/exurban development near cities and towns along the river corridor. The Billings area accounts for 54 percent of the total urban-caused conversion. Reach B2 alone experienced a loss of nearly 50 percent of its woody riparian acres.
  - The loss in riparian cover between 1950 and 2011 (6,858 acres) was offset by the encroachment of riparian vegetation into abandoned or blocked side channels, primarily in regions C and D, post 1976.
  - Closed timber area has increased while shrub and open timber have declined, indicating senescence of older cottonwood forests without a commensurate increase in younger age classes. The riparian mosaic below the Bighorn River, where channel migration has appreciably slowed since 1976, has become more simplified with less diversity in the number, size, and shape of riparian cover types.

- About 20,000 acres of riparian cover has been isolated from the 100-year inundation area by earth-fill prisms, primarily related to agricultural and transportation features. Isolated riparian habitat is at greater risk of reduced connectivity, health, invasion by exotic species, or conversion to other uses.

- Riprap and flow deflectors installed to prevent channel migration affect about 11,000 acres of riparian vegetation on the Yellowstone River; primarily in regions B and C. Elimination of channel migration will result in less riparian and wetland recruitment in the future, leading to a long-term decline in riparian vegetation.

- Increased invasion by exotic species due to moisture-stressed riparian vegetation is likely, which results in diminished habitat and forage values.

- Indications are that in regions C and D below the Bighorn confluence, the rate of conversion of riparian to channel has declined since 1976, signaling a reduction in channel dynamics and riparian exchange or turnover.

- Natural riparian succession (riparian to channel and vice versa) driven by channel migration or floodplain turnover is responsible for more than twice as much total change in all riparian classes between 1950 and 2001 as is land use conversion (28,400 acres vs. 11,000 acres).

- Livestock grazing likely results in reduced native riparian species diversity, community composition, and structure, and facilitates invasion by nonnative, invasive species.

- Russian olive occupies about 3,000 acres of the 100-year inundation area and increases in a downstream direction from Region PC through C. Russian olive occurs most frequently in the shrub and open timber categories and is correlated to less confined geomorphic reaches, with invasion appearing to occur into abandoned channels and islands.

- Many additional invasive species are poised to invade the Yellowstone River watershed.

4.7.3 Riparian Extent and Composition Changes

Very limited suitable historical data are available to represent the extent of riparian vegetation prior to 1950 in the Yellowstone River corridor. Early records and historical documents do indicate that the pre-settlement (early 1800s) Yellowstone River corridor supported abundant stands of cottonwood and other woody species throughout the project area, except where the floodplain was naturally constrained by geology (Confluence 2003). Unquestionably, riparian habitat extent has been substantially reduced since the area was settled. Various authors have estimated that between 66 to 95 percent of riparian habitat has been converted to other uses in the western U.S. so it is reasonable to assume that similar changes may have occurred in the Yellowstone corridor (Swift 1984; Krueper 1993; Patten 1998; Poff et al. 2012). Northern deciduous cottonwood forests occurring primarily as riparian communities made up around 1 percent of the Yellowstone River Basin in 2002 (Zelt et al. 1999).

The USFWS's National Wetland Inventory (NWI) program conducted wetland and riparian mapping within the Yellowstone River corridor in the mid-2000s (USFWS 2014). Merigliano and Polzin (2003) studied riparian plant communities in the upper Yellowstone River in Park County. They determined that, compared to 100 years ago, riparian communities generally have much the same appearance and composition; however, there has been a marked reduction in floodplain turnover rates commensurate with reduced extent of cottonwood forests and age distribution. The loss in riparian extent due to natural succession was about double the rate of loss to agricultural conversions, which indicates a potential long-term decline in riparian forest as the forest ages.

Looking at geomorphic Regions A to D riparian data between 1950 and 2001 indicates that riparian extent has been fairly stable. Table 4-15 presents the summary results of the Yellowstone River Riparian Mapping project (DTM and AGI 2008a) conducted using the 100-year inundation area, plus a one-tenth mile buffer as the analysis area.

Riparian cover types used in the study are shrub, closed timber, and open timber for all regions. A number of reaches show that riparian losses on one bank are matched by gains in riparian extent on the other (A3, B11, C10, and D5), reflecting a dynamic equilibrium in channel migration. Closed timber generally shows the least change over time in all reaches which, as this typically represents the middle successional stage, is expected.

Total riparian acres between 1950 and 2001 did not change appreciably, declining by about 3 percent. On average, riparian cover comprises roughly 20 percent of the area within the 100-year inundation boundary, but varies between three and 44 percent at the reach level primarily due to geomorphic attributes of the channel and floodplain. More variation is seen within the classes of riparian cover over time reflecting the ebb and flow of temporal riparian succession driven primarily by channel migration. This variation in regions PC, A, and B, for the most part reflects active flooding and channel migration provided by the relatively uncontrolled aspect of the upper Yellowstone's free-flowing and relatively little modified hydrology (see Section 4.3 Hydrology).

Table 4-15
Yellowstone River (Springdale to Mouth) Riparian Extent (1950, 1976, and 2001)

	1950	1976	2001
Shrub (ac)	25,332	19,360	19,144
Closed Timber (ac)	38,889	36,289	42,620
Open Timber (ac)	12,319	10,661	12,595
Total (ac)	76,600	66,310	74,363
All Land (ac)	347,841	347,850	347,841
Riparian Composition	22%	19%	21%
High (%)	44%	42%	42%
Low (%)	3%	4%	2.7%
Reach High	D11	D11	D11
Reach Low	C21	D1	D1

Source: DTM and AGI 2008a.

Note: While overall riparian extent and composition has remained relatively static over time, individual reaches show significant variability in extent and composition.

Figure 4-115 and Figure 4-116 show change in the extent (acres) of shrub and open timber categories by Region. In general, Region A has several reaches that exhibited large gains in riparian cover due to colonization of open channel and herbaceous areas by shrubs (600 percent), although region-wide there was a net loss of shrub cover (-28 percent)(Figure 4-115).

Similar results are found for Region B but with a net gain in shrub extent (31 percent). A majority of reaches show an overall loss of riparian cover but with a net gain for the region due to large gains in shrub and open timber in several reaches.

In Region C, gains about equaled losses of riparian cover acreage. The change in shrub acres increased, with the median being 10 percent, although some reaches increased by over 100 percent. The extent of open timber change in acreage increased in most reaches above Forsyth (C10) between 1950 and 2001, indicating isolation of the stands due to floodplain dikes and bank armoring preventing channel migration flooding. Below Forsyth, closed timber typically declined.

Within Region D, a series of reaches with losses in shrub and open timber cover and consistent gains in closed timber between 1950 and 2001 is evident between reaches D6 to D15. These data suggest that the riparian forest cover is maturing with open timber becoming decadent and falling out of a riparian class with little new establishment of shrubs and young trees. A possible cause of the noted trend in addition to agricultural conversion is related to changes in the hydrograph downstream of the Powder River (Section 4.3 Hydrology). The regional change in shrub extent shows a 41 percent mean loss, again likely related to diminished channel migration with the noted decreased high flows, and possibly increased ice scour under the effect of increased winter flows (DTM and AGI 2008a). Section 4.5.3.3 identifies that floodplain turnover rates have been reduced from 520 acres per year between 1950 and 1976 to only 340 acres per year from 1976 to 2001, with a reduction in recruitment of closed timber of about 56 acres per year. Figure 4-115 and Figure 4-116 depict the sizeable regional losses in woody riparian class percent for the shrub and open timber categories.

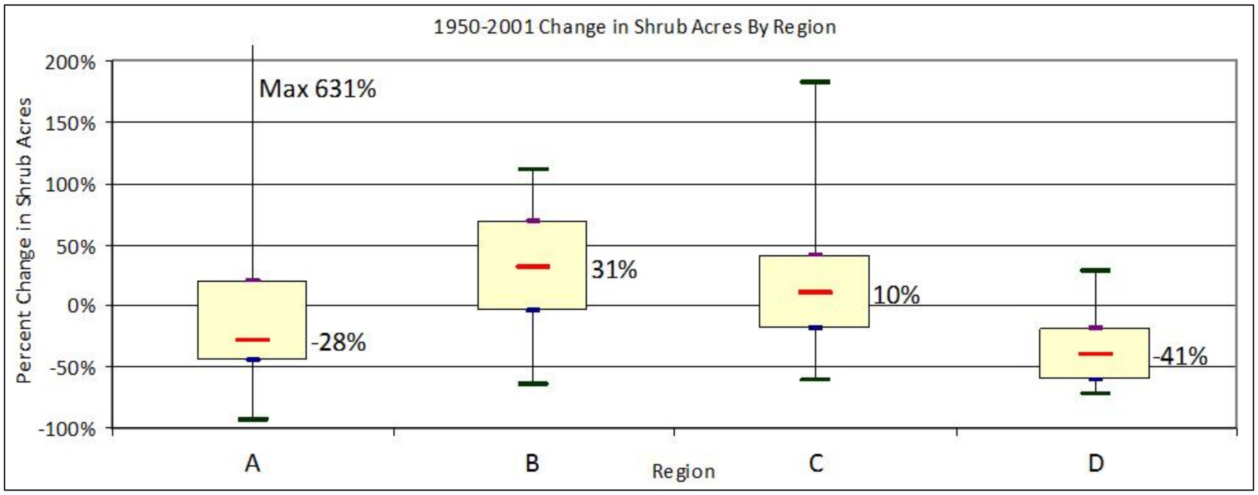


Figure 4-115 Statistical summary of change in shrub (S) acres by region from 1950–2001

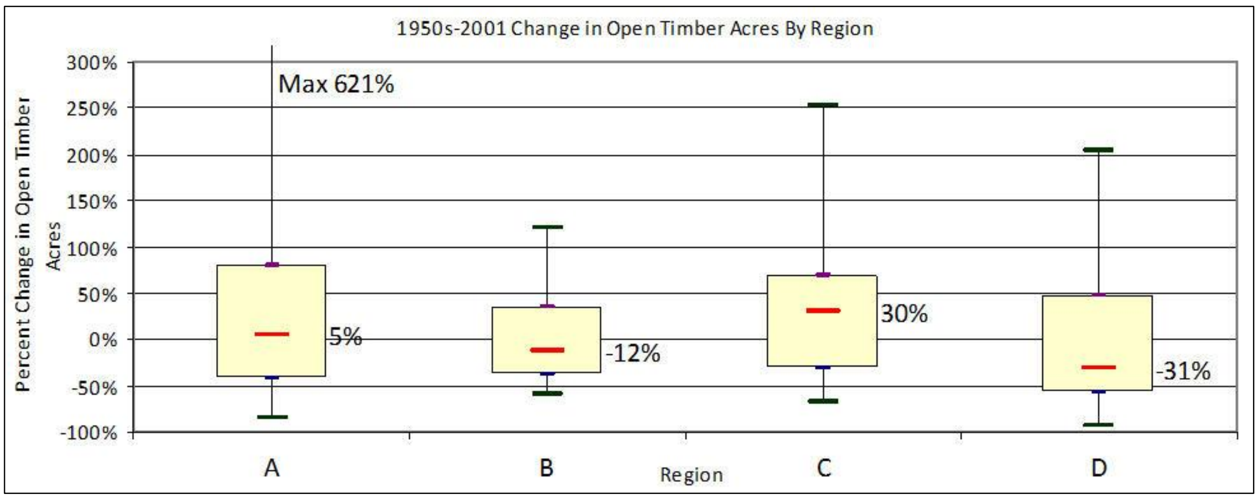


Figure 4-116 Statistical summary of change in open timber (TO) acres by region from 1950-2001

The number and spatial pattern of riparian polygons or patches have also been altered over time. Figure 4-117 depicts the decline in number of riparian polygons between 1950 and 2001, particularly for the shrub and open timber category.

Spatial analysis of riparian polygon shape-complexity relationships reflected by Perimeter Area Ratio (PARA) values indicates that there has been a subtle decline in the shape of shrub polygons since the 1950s, but not to any appreciable extent (DTM and AGI 2008a). Also, PARA values do not show direct relationships to geomorphic types, indicating that other factors have had a greater influence on polygon shape and size.

In contrast to PARA values, the orientation of riparian polygons expressed by nearest neighbor distance is well correlated to channel geomorphology. Nearest neighbor distance values typically show that similar riparian patches are closer together in unconfined channel types, suggesting that the more frequent channel migration and riparian turnover that occurs in less confined channel types creates more complexity and proximity of riparian cover patches. The relatively infrequent channel migration exhibited in confined reaches results in larger nearest neighbor distance values.

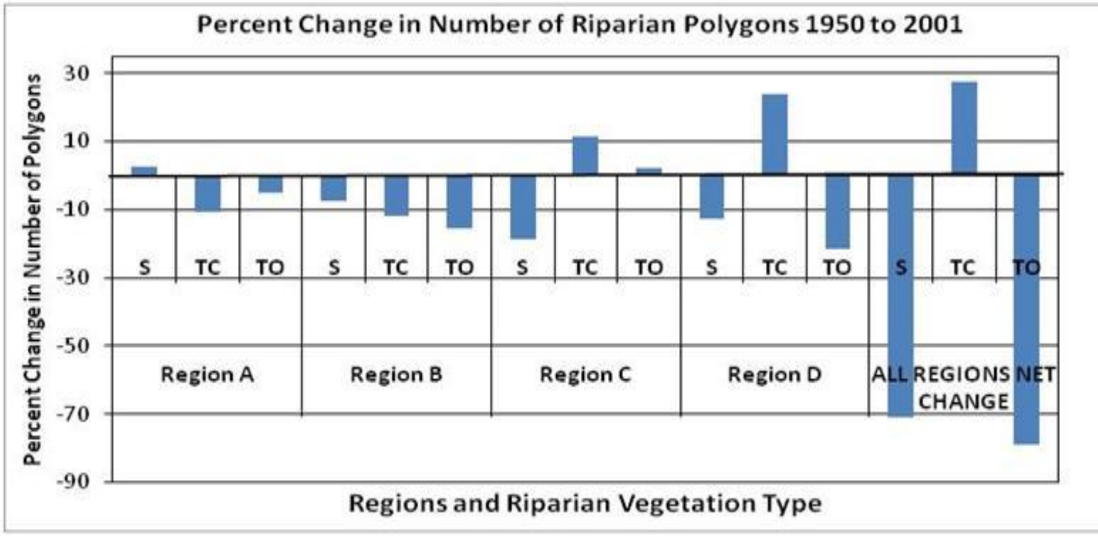


Figure 4-117 Percent change in riparian cover polygon count from 1950 to 2001

Note: Sharp decline in shrub (S) and open timber (TO) classes and gain in closed timber (TC) class in Regions C and D

To save space and with similar results in other regions, nearest neighbor distance values for only Region D are shown in Figure 4-118 to illustrate this discussion. Analysis for all regions shows that nearest neighbor distance values for the open timber riparian class are much greater than closed timber or shrub classes and have increased since the 1950s in regions C and D, especially in less confined channel types.

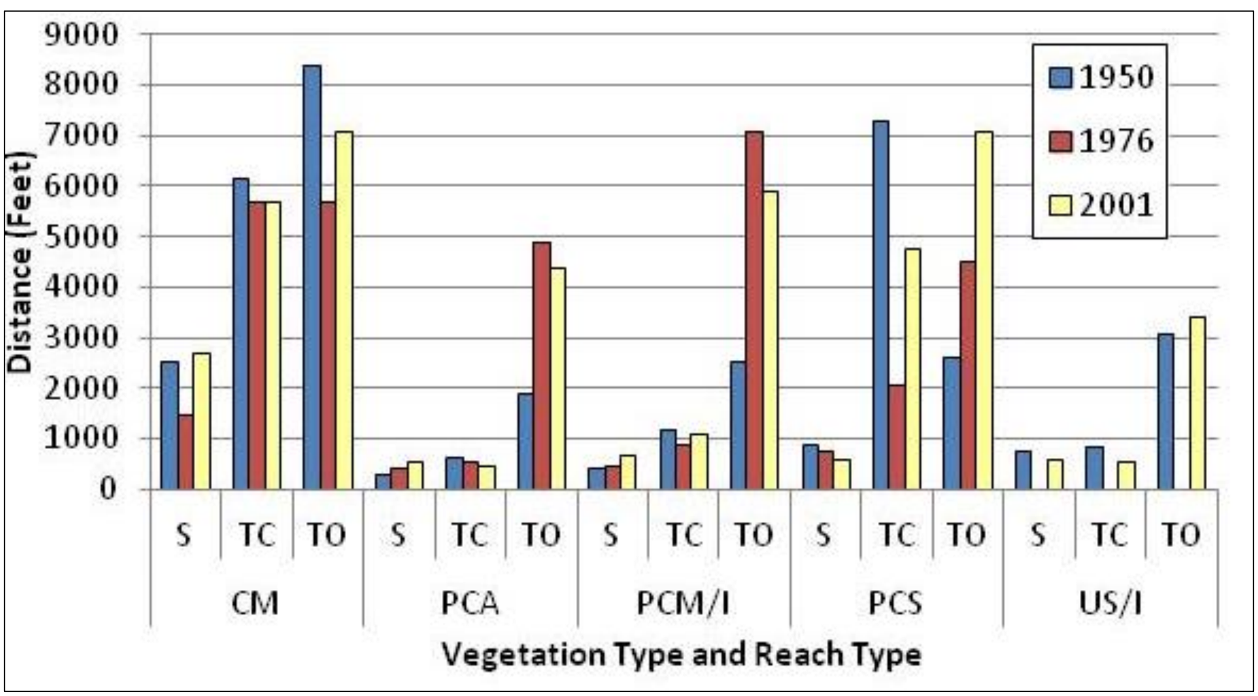


Figure 4-118 Nearest Neighbor Distance values for Region D, 1950–2001

Key findings on riparian cover types and extent are as follows:

- Much of the extensive cottonwood forests reported by early day explorers in broad valley areas along the Yellowstone River no longer exist, having been harvested or cleared and converted to other land uses prior to 1950. As of 2001, riparian extent makes up about 21 percent of the 100-year inundation area but varies from 3 to 44 percent between reach types.

- Riparian extent and density is strongly related to geomorphic reach type with riparian vegetation showing greater correlation to less confined reaches having multiple, braided channels and islands.

- The shrub riparian cover acreage has declined by 24 percent while closed timber showed a 10-percent increase and open timber increased by 2 percent, indicating that shrub habitat was not being replaced as the timber categories age, possibly suggesting some imbalance in the dynamic equilibrium between riparian gains and losses.

- The loss in riparian cover between 1950 and 2011 (6,858 acres) was offset by the encroachment of riparian vegetation into abandoned or blocked side channels, primarily in regions C and D, post-1976.

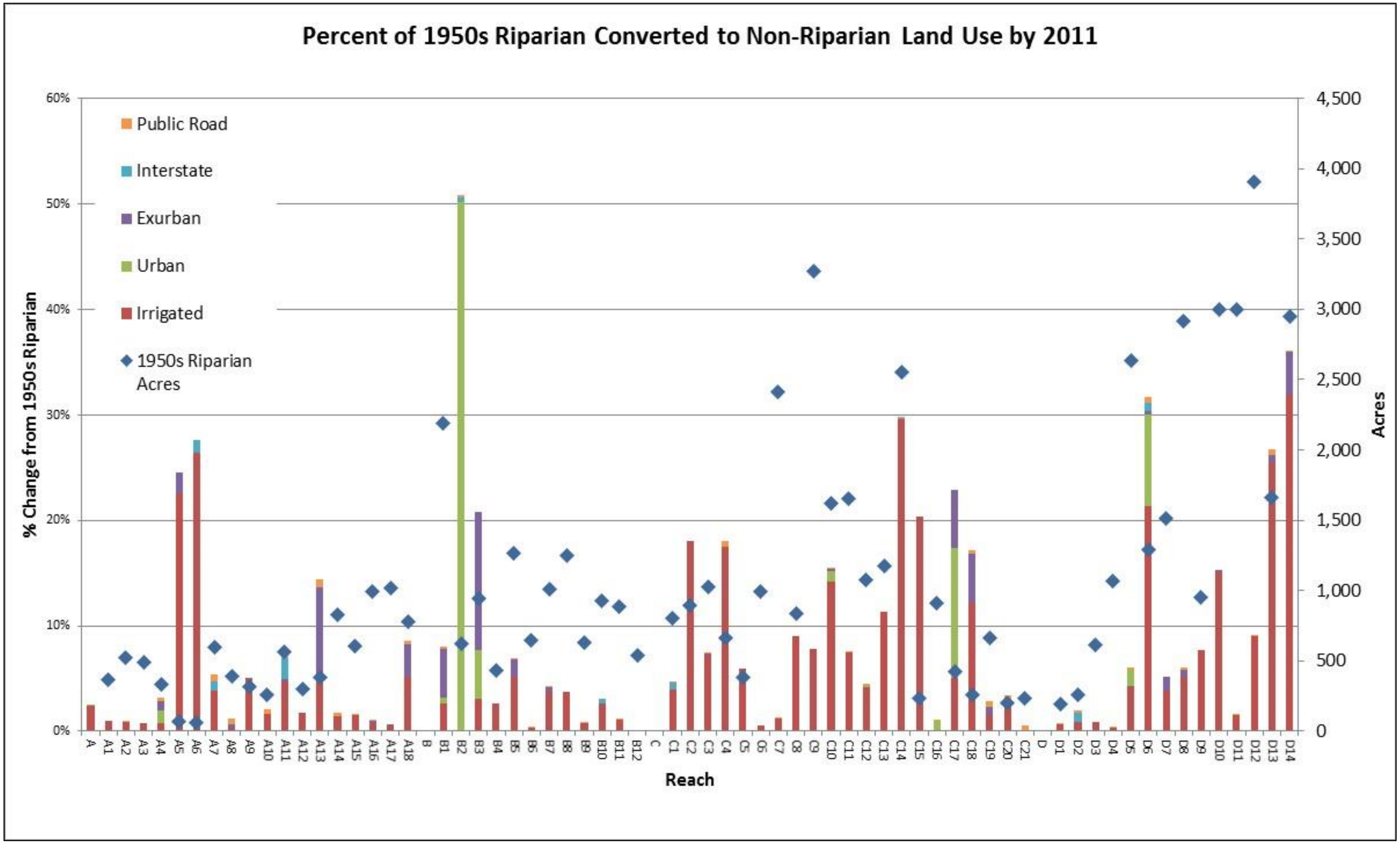
- The number of closed timber polygons has increased while those of shrub and open timber have declined, indicating senescence of older cottonwood forests without a commensurate increase in younger age classes (shrub category). The size and shape of most shrub patches has grown slightly while riparian polygons of similar type are further apart in more confined reaches. Together these changes demonstrate that the riparian mosaic below the Bighorn River—where channel migration has appreciably slowed since 1976—has become more simplified with less diversity in the number, size, and shape of riparian cover types.

4.7.4 Land Use Conversions

In rural areas, conversion to agricultural uses includes drainage and land clearing for crop production and pasture. Closer to river-based communities, conversion to urban and industrial sites, and exurban development for rural home sites has taken place as amenity-based buyers seek to exploit the numerous amenities provided by the Yellowstone's riparian areas.

Figure 4-119 depicts conversions of 1950s woody riparian habitats to other land uses as of 2011. Irrigated agriculture is the primary cause of conversion except in Reach B-2, in which urban conversion is the leading cause. Irrigation conversions, primarily in regions C and D, resulted in the loss of 5,600 acres (about 8 percent of the total riparian area within the 100-year inundation boundary). In Reach B2, 314 acres were lost with over 50 percent of the losses due to urban conversion. Exurban development, roadways, and the railroad have had a negligible post-1950 effect on riparian conversion in this analysis (except in Reach B2). Overall, approximately 10 percent of the riparian habitat present in 1950 has been converted to another non-riparian land use. Pre-1950s conversions, particularly for agriculture and the railroads, was likely more significant, as noted earlier (DTM and AGI 2008b).

Transportation land uses can affect riparian systems both by direct land use conversions and from floodplain isolation and channel migration restrictions. Direct conversion from riparian to transportation land uses has removed only a minor amount of riparian habitat since 1950. About 86 acres of riparian habitat present in 1950 was converted to roads; a relatively insignificant amount (0.1 percent). Forty-two of the 65 reaches showed some minor conversion occurring with a little more than 40 percent of the total riparian-to-road conversion occurring in Region D (35.1 acres).



Source: Yellowstone River Land Use Mapping and Analysis (DTM and AGI 2012)

Figure 4-119 Extent of change of riparian area to other non-riparian land uses

Although Interstates 90 and 94 were built post-1950, direct conversion of riparian habitat by the interstate highway system is also a minimal component of overall riparian losses. Analysis of the riparian and land use mapping determines that only about 44 acres of riparian habitat present in 1950 (less than 0.06 percent) was converted to interstate highway. Ten reaches had interstate conversion; however, nearly one-quarter of the total change occurred in Reach A11.

Transportation corridors may also affect terrestrial wildlife habitat due to the proximity of the corridor and the associated disturbance and fragmentation of riparian connectivity. Mortality caused by impacts with vehicles in addition to the noise and disturbance associated with transportation activity diminishes the wildlife value of the affected habitat (Forman and Lawrence 1999). In some places, the transportation corridor consists of the railroad, interstate lanes, and a frontage or county road in parallel, creating a 300+-foot-wide corridor that is an effective barrier to many terrestrial and avian species that make use of the riparian corridor. While the conversion of riparian acreage to transportation use is not substantial, the loss of connectivity may be more important. As a good example of this effect, one of the primary causes of the decline of the greater sage-grouse (*Centrocercus urophasianus*), which is not a species considered here, is the loss of connectivity of sagebrush habitat throughout large portions of the intermountain west. The loss of connectivity and the mortality of species using riparian habitats is a qualitative impact that cannot be quantified for the purposes of this study, yet is an important consideration in evaluating riparian impacts due to current and future transportation facilities.

More recently, oil and gas development in the Williston Basin in North Dakota has expanded into Montana in the lower Yellowstone River corridor, particularly impacting Richland and Dawson counties (Board of Oil and Gas Conservation 2013). Land use mapping completed within the 100-year inundation zone plus a one-half-mile-wide buffer identified 51 active drilling/well pads occupying about 144 acres within the river corridor in Region D in 2011 (DTM 2013). Many of the pads and access roads are located within agricultural fields, but an unknown number have been built within riparian areas. Given the rapid development in the Glendive and Sidney areas, the number of pads and associated access roads has likely increased since the land use mapping was completed.

Less direct impacts to riparian resources are related to alteration by grazing, fire, and invasive species. Hydrologic and geomorphic alterations noted on the Yellowstone include water (surface and ground water) withdrawals, tributary dams, bank stabilization structures, channelization, and levees and side channel plugs and are discussed further in following sections.

Following are the salient points regarding conversion of riparian habitat to other land uses:

1. System-wide, there has been little net change in riparian extent between 1950 and 2001. Some individual reaches, however, have experienced significant change from land use conversion:
    a. Over 5,500 acres of 1950s riparian cover were converted to irrigated agricultural land uses by 2011, with 2,900 acres converted in Region D alone.
    b. The net loss of riparian cover to agriculture and other land uses has been mitigated by a gain in riparian cover over time due to the encroachment of riparian species in abandoned side channels in regions C and D.
    c. Over 1,100 riparian acres—or about 1.5 percent of the total 1950s woody riparian area—were converted to urban/exurban development near cities and towns along the river corridor. The Billings area accounts for 54 percent of the total urban-caused conversion. Reach B2 alone experienced a loss of nearly 50 percent of its woody riparian acres, primarily between 2001 and 2011.

2. Direct conversion of riparian habitat by transportation-related land uses has been minimal overall since 1950; however, indirect impacts associated with the transportation corridors could have more substantial effects on riparian habitat by affecting the long-term values associated with those areas.
3. About 20,000 acres—or 6 percent of all riparian cover—has been isolated from the 100-year inundation area by earth-fill prisms, primarily related to agricultural and transportation features. Isolated riparian habitat is at greater risk of reduced connectivity and health, invasion by exotic species, or conversion to other uses.
4. Riprap and flow deflectors installed to prevent channel migration affect about 11,000 acres—or 3 percent of riparian vegetation on the Yellowstone River. Elimination of channel migration will result in less riparian and wetland recruitment in the future, leading to an eventual decline in Yellowstone River riparian habitat as natural succession changes the areas to upland grasslands.

4.7.5 Summary of Off-Channel Impacts (Hydrologic Alterations)

The hydrologic analysis in Section 4.3 documents significant reductions in May through June flood flows beginning at Billings, with even more pronounced reductions below the mouth of the Bighorn River (regions C and D). These reductions have resulted in the isolation and loss of side channels and altered channel dynamics and floodplain turnover due to numerous water withdrawals for irrigation and other water uses above the Bighorn confluence and primarily due to operation of Yellowtail Dam below the Bighorn (Chase 2013). Reductions in late summer streamflow were also identified in the hydrologic analyses (Chase 2014). Higher base and winter flows were determined not to impact riparian systems to an appreciable degree.

Numerous studies in similar river systems have highlighted the importance of large, peak flows as drivers of channel migration and floodplain turnover to maintain wetland and riparian extent in systems comparable to the Yellowstone River (Rood et al. 2008; Braatne et al. 2007; Kudray and Schemm 2006; Merigliano and Polzin 2003; Scott et al. 1997; Rood and Mahooney 1996; Braatne et al. 1996; Mahoney 1995) (see Figure 4-120). Figure 4-121 illustrates how channel migration creates floodplain turnover through the erosion and deposition processes. Hydrologic alteration further disrupts riparian systems already affected by channel and floodplain restrictions and other stressors. Without the changes in channel migration driven by flood flows (floodplain turnover), riparian habitats are diminished in spatial extent as well as function due to simplification in vegetation and structure. Analysis of the Yellowstone River riparian cover class extent with respect to geomorphic channel type shows a strong positive correlation to the more dynamic reaches where channel migration is driven by flood flows (Figure 4-121) (DTM and AGI 2008a), a finding also noted by Merigliano and Polzin (2003) in the upper Yellowstone study area.

As hydrology and geomorphic processes are simplified, not only is the extent of riparian cover reduced but the size and distribution of riparian polygons also are altered. Reductions in channel migration and floodplain turnover due to hydrologic alterations or other causes will result in reduced riparian recruitment over time (Boggs 1984) as well as greater simplification of riparian community native species complexity and diversity (Eggers 2005).

Figure 4-122 and Figure 4-123 show net gains and losses in riparian cover by reach (i.e., floodplain turnover) due to channel migration for the 1950–1976 and 1976–2001 time periods. Over 55 percent of the net riparian gain occurred in Regions C and D. The analysis strongly suggests that the braided and anastomosed reaches have seen declines in riparian turnover rates, reduced new riparian recruitment rates, and lost side channel length and area, primarily below the Bighorn River at rates that suggest these lower river reaches no longer exhibit a steady-state mechanism over the time period studied.

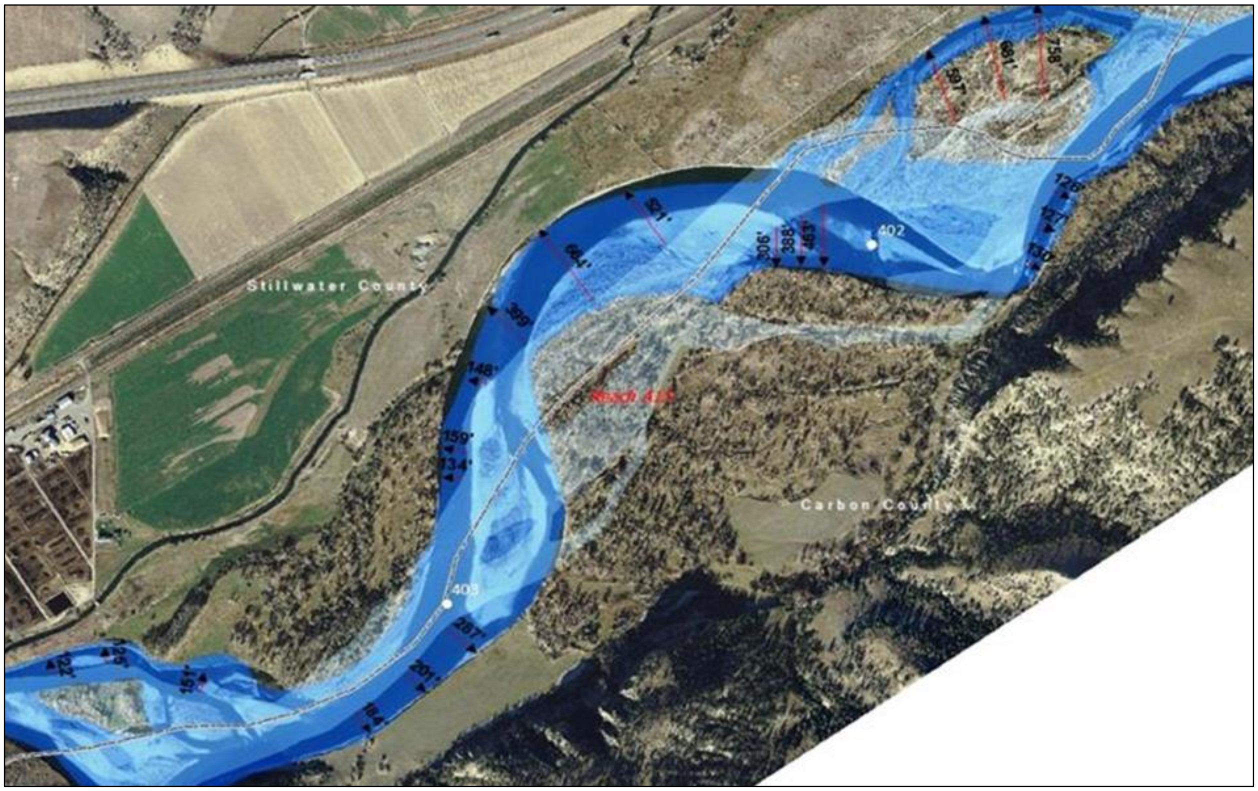


Figure 4-120 Comparison of 1950 to 2011 channel location in Reach A15

Note: The location of the 1950 channel in Reach A15 (partially confined, braided) is shown in light blue shading while the 2011 channel location is shown in darker blue. The arrows indicate the direction and extent of channel movement since 1950 (61 years). The agricultural and riparian areas eroded away as the channel migrated are now a mosaic of wetland and riparian sites providing a variety of aquatic and terrestrial habitats. Note that the current channel area approximately equals the area of the abandoned 1950 channel, indicating a dynamic equilibrium in this section of river. At the rate of channel movement indicated here, the floodplain turnover rate is between 400 and 600 years. This rate is compared to the calculated rates for braided reaches in Park County of between 550 and 1700 years (Merigliano and Polzin 2003).

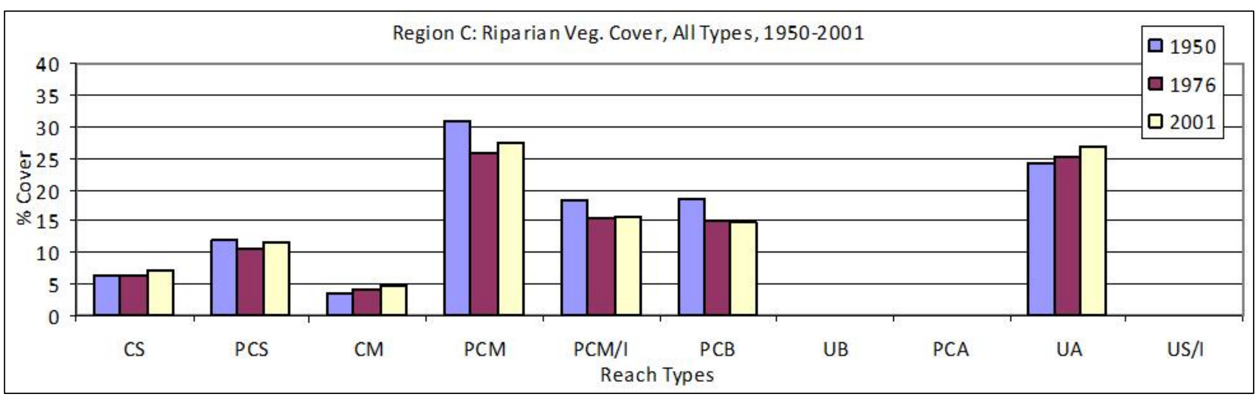


Figure 4-121 Riparian cover extent as a function of channel type in Region C

Note that channel types UB, PCA, and US/I are not present in Region C

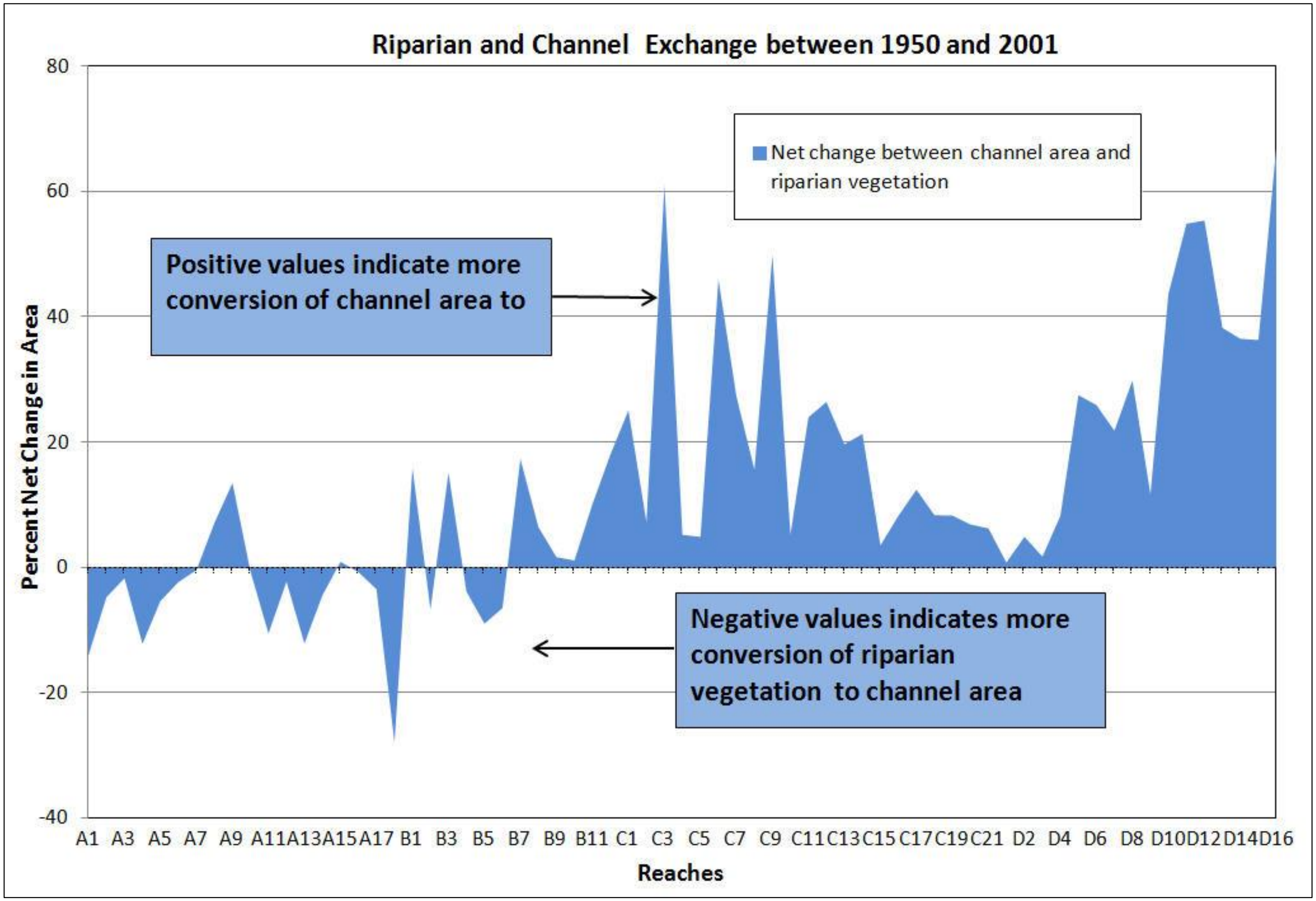


Figure 4-122 Net change in riparian and channel area between 1950 and 2001

Channel areas have been converted to riparian habitat in Regions C and D to a greater extent and magnitude than in Regions A and B

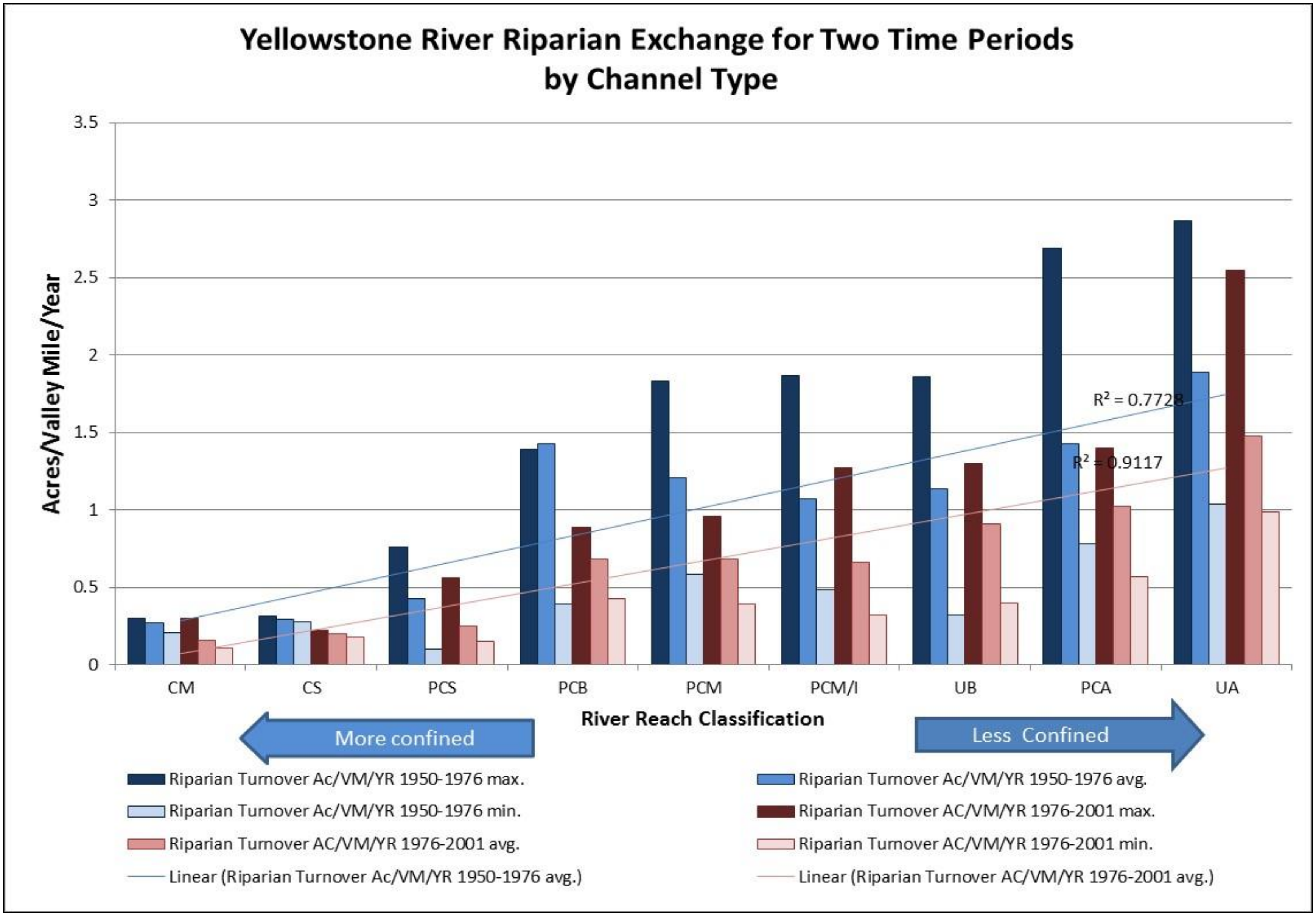


Figure 4-123 Riparian exchange or turnover stratified by channel classification for both the 1950–1976 and the 1976–2001 time periods

Reaches in regions A and B demonstrate more equivalent gains and losses in riparian cover during the period of study. The reductions in discharge events detailed in Section 4.3 Hydrology (around 15,000-cfs reduction in mean daily discharge) have led to reduced channel area and opportunity for riparian recruitment below the mouth of the Bighorn River since fewer sand and gravel bars are created and maintained each year (Boggs 1984). Similar reductions and impacts have been noted for other streams in the western U.S. (Knight et al. 2014; Rood et al. 2008; Braatne et al. 2007; Kudray and Schemm 2006; Merigliano and Polzin 2003; Scott et al. 1997).

Changes in late summer low flows are also linked to stresses on riparian and wetland systems as the lower discharge level drops the local water table during a period of high plant stress (e.g., elevated air temperature and evapotranspiration requirement), making the riparian systems susceptible to infestation by more drought-tolerant invasive species (Ellis 2008; Eggers 2005; National Research Council 2002) See Section 4.10 for further discussion of invasive species' impacts on riparian areas.

In summary, the hydrologic alterations to the Yellowstone River system have the following potential impacts on riparian plant communities:

1. The observed increase in riparian cover post-1976 due to expansion into abandoned seasonal high-water channels (regions C and D) that are no longer accessed by flood flows and onto open bars is not sustainable over time.

2. Long-term loss of riparian extent is predicted as well as shifts in riparian species diversity and age due to reduction in riparian recruitment and channel-riparian exchange as a result of diminished channel migration. Without regular channel forming flows to drive channel migration, there will be fewer suitable sites for riparian species recruitment. Where regeneration does occur at a lower elevation above the water surface, ice scour and subsequent flooding can lead to higher mortality rates. A temporal shift to less diverse, more widely spaced, and predominately older age classes of woody riparian cover is now evident in regions C and D.

3. Increased invasion by exotic species due to moisture-stressed riparian vegetation is likely, which results in diminished habitat and forage values.

4. Indications are that in regions C and D below the Bighorn confluence, the rate of conversion of riparian to channel has declined since 1976, indicating a reduction in channel dynamics and riparian exchange or turnover.

5. Natural riparian succession (riparian to channel and vice versa) driven by channel migration or floodplain turnover is responsible for more than twice as much total change in all riparian classes between 1950 and 2001 as is land use conversion (28,400 acres vs. 11,000 acres).

4.7.6 Summary of Floodplain Isolation Impacts

Dikes, levees, and placement of road and railroad prisms within the floodplain create barriers to floodwater accessing the full extent of the floodplain. While elimination of flooding was not always the primary intention of the fills, the results are often the same as overbank flows are eliminated from areas behind the fills. The effect of the restriction is to alter the process through which floodwater periodically inundates the affected riparian area, bringing water and nutrient-rich sediments (Zaimes 2007). The restrictions also then eliminate the function of riparian vegetation to trap flood-borne sediment and storage of flood flows, which results in higher volume and velocity of floodwaters downstream. While indirect impacts do not destroy the vegetation, the result is to effectively eliminate the function of the floodplain to trap and store sediment, detain floodwaters and enhance water storage, and provide wildlife habitat. Over time, most of the riparian vegetation in cutoff floodplain areas is drastically diminished in complexity and structure (no data for this effect) in addition to the loss of function similar to that shown for hydrologic modification and exposure to flooding (Braatne et al. 1996; Auble et al. 1994; Brinson 1981).

The floodplain hydraulic analysis (Section 4.4.3) determined that nearly 20,000 acres of 1950s riparian mapped acres have been isolated by floodplain (100-year) restrictions along the corridor with significant occurrences in regions C and D. Figure 4-124 shows the relative contribution of the various causes of floodplain isolation. Figure 4-125 depicts the extent and causes of floodplain isolation by reach. Agricultural-related floodplain restrictions are the most significant cause (56 percent) of riparian isolation followed by transportation-related causes (33 percent). Primary agricultural sources are field leveling, irrigation infrastructure (ditches and canals), and levees. Nearly 80 percent of the isolated riparian cover is herbaceous in nature. These lands are primarily used for unimproved dry and irrigated pasture and hay land.

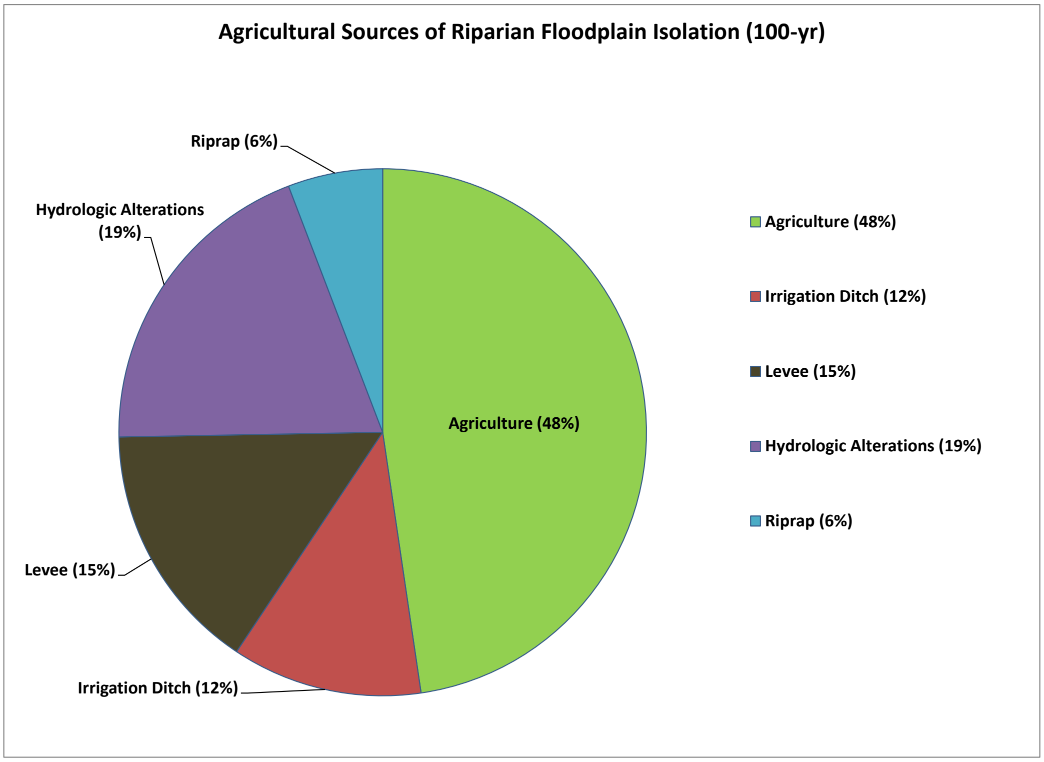


Figure 4-124 Causes of riparian Isolation from the 100-year inundation boundary

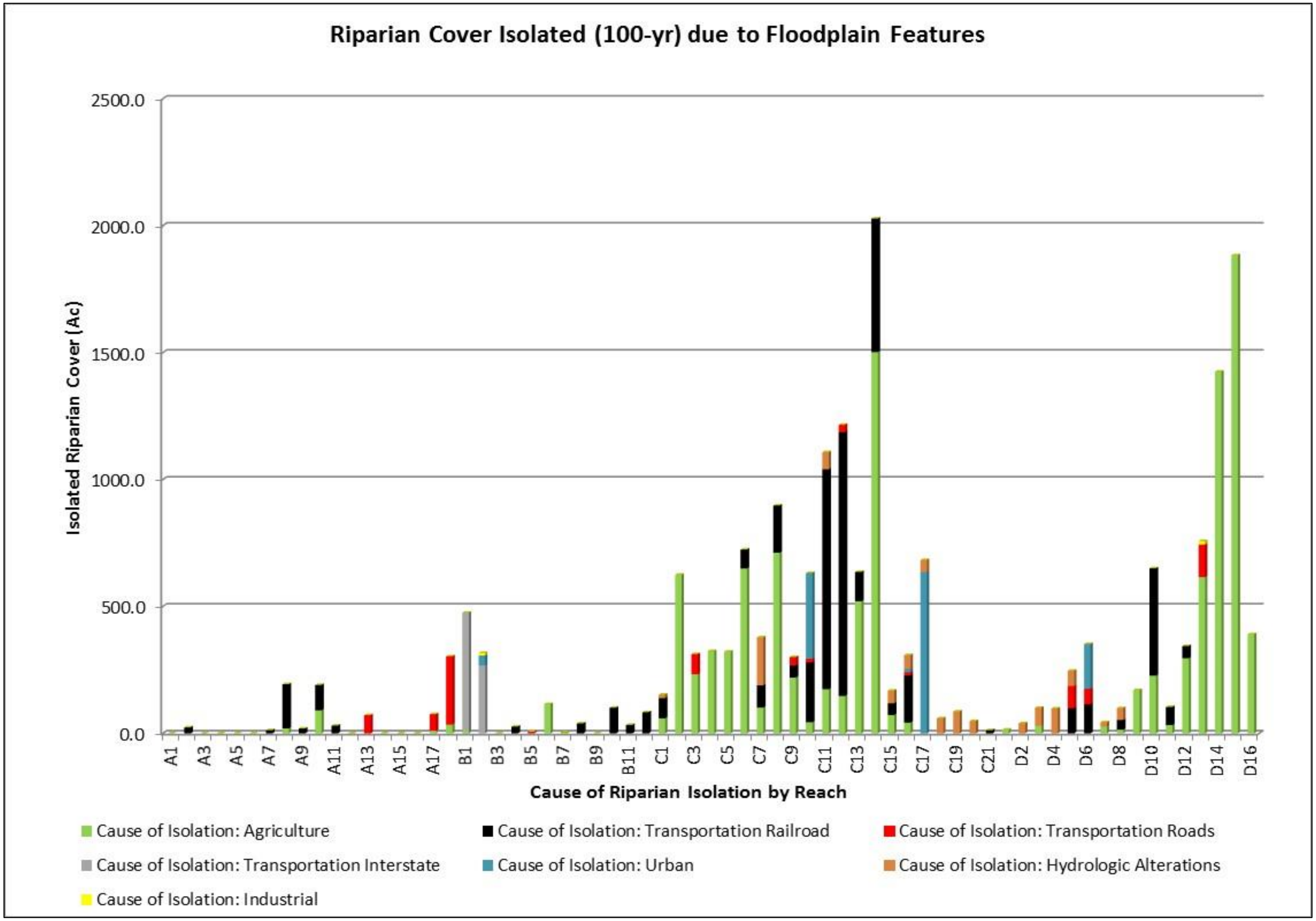


Figure 4-125 Extent of riparian cover isolated by floodplain physical features on the Yellowstone River

Note: Extent of riparian cover is greater in Region C and the lower reaches of Region D, with agricultural floodplain features being the leading cause of isolation. Both the existing rail line and the abandoned Milwaukee Road fill are included under the "Transportation Railroad" cause.

Without periodic flushes of water, sediment, and nutrients, riparian areas dry out and become decadent (Braatne et al. 1996; Miller et al. 1995; Brinson 1981) and in many cases are then converted to another land use. Cut off from the channel and flood flows, the riparian areas can no longer provide critical environmental services.

Altered hydrology is also a cause of riparian isolation due to the diminished elevation of flood discharge. Below the mouth of the Bighorn River, the reduction in area flooded by a 5-year frequency flood is more than double that above the mouth. Some 2,400 acres of irrigated land in the 5-year floodplain was woody riparian habitat in 1950. Conversion to irrigated land may have been facilitated by diminished riparian health as a result of the reduced frequency of inundation.

Following is a summary of findings related to floodplain isolation of riparian systems:

- About 20,000 acres of riparian habitat are disconnected from the 100-year inundation area due to placement of dikes, levees, and other fills within the floodplain. About 16,000 affected acres (80 percent) are herbaceous riparian cover.
- Agricultural-related floodplain features are the leading cause of riparian isolation from the 100-year inundation area, affecting some 11,000 acres with the majority of affected acres in Regions C and D.
- Transportation is the second leading cause of riparian isolation occurring primarily in Region C, affecting about 6,500 acres of riparian habitat.
- Altered hydrology is responsible for isolation in the lower river below the Bighorn due to reduction in flood discharge.
- Isolated riparian areas have reduced function and provide diminished ecological services to the river system and may be at greater risk of conversion as flood frequency is diminished.

4.7.7 Summary of Channel Migration Restriction Impacts

Riparian recruitment, as noted elsewhere, is driven by erosion and deposition provided through the channel migration process. Early successional riparian species like willow and cottonwood germinate on the fresh alluvial deposits created from eroding banks upstream. Bank armor on the Yellowstone River has taken many forms over the years from loose rock pilings to oriented rock structures called bendway weirs, groins, or vanes. When successfully applied, bank stabilization structures, by design, prevent or, at a minimum, drastically restrain channel movement. Elimination of the channel migration process then removes the opportunity for new riparian species to grow and replace the decadent stands of riparian shrubs and trees as riparian succession proceeds elsewhere. Without recurring or periodic recruitment, complex mosaics of riparian habitats are simplified and fragmented over time (Knight et al. 2014; Braatne et al. 2007; Zaimes 2007; National Academy of Sciences 2002). Structures that serve to limit horizontal channel movement and flooding tend to have the greatest potential impact in stream settings that are naturally less geomorphically restricted with broader floodplains and extensive riparian habitat (Auble et al. 2004; Merigliano and Polzin 2003).

The Channel Migration Zone (CMZ) mapping (DTM and AGI 2009) was used to evaluate the extent and causes of restrictions to channel migration that affect riparian habitat (AGI and DTM 2004). Riparian mapping affected by Restricted Migration Areas (RMAs)[3] totals about 11,200 acres or about 7 percent of the riparian area mapped within the 100-year inundation boundary. Bank armor is the leading cause of direct human-induced channel migration restrictions that affect riparian habitat in the river corridor (Figure 4-126). Rock riprap and related flow deflector installations are responsible for over 70 percent of the migration restricted riparian area. Transportation-related restrictions are relatively minor and occur sporadically throughout regions A through D. The extent of bank armor and floodplain restriction within each reach ranges from 0 to over 60 percent of bank length.

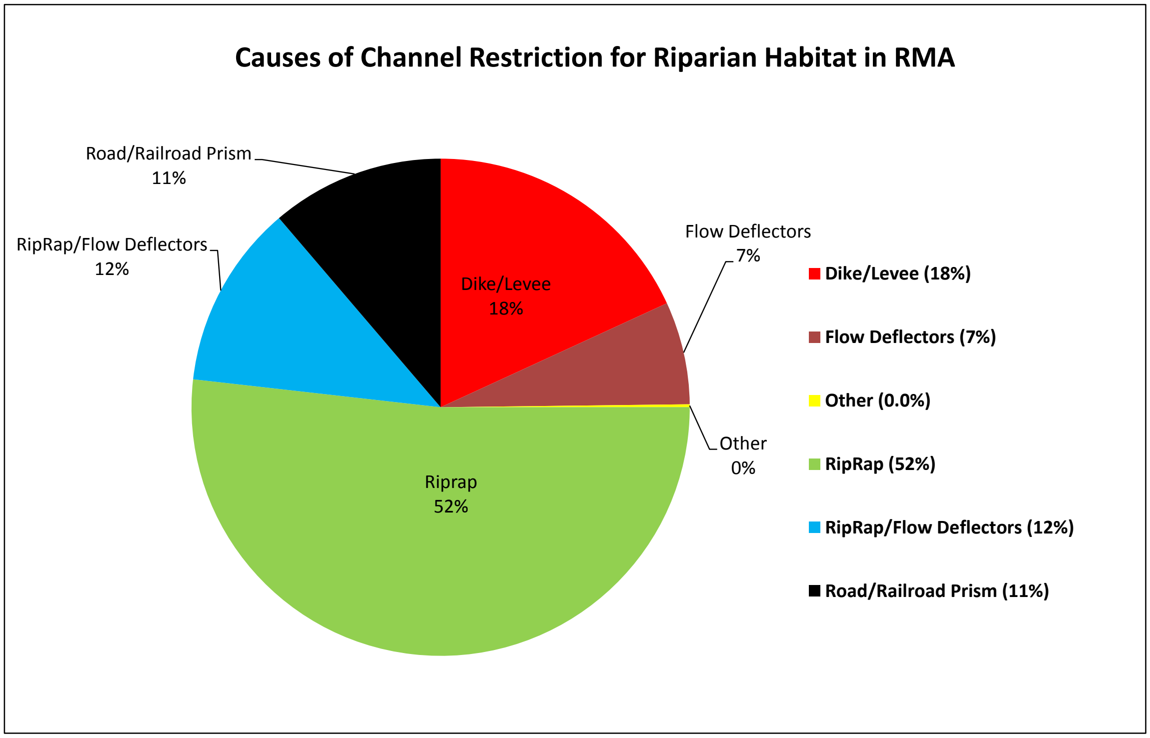


Figure 4-126 Cause of channel migration restriction adjacent to riparian habitat along the Yellowstone River

Figure 4-127 depicts riparian cover classes affected by RMAs for each reach. The chart illustrates again that herbaceous cover is affected to the greatest extent by channel migration restrictions. The majority of RMA riparian habitat occurs in regions B and C. Reach B1 has the greatest extent of mapped riparian area affected, over 1,100 acres of which over half is herbaceous cover; however, there are also about 475 acres of woody riparian cover impacted (S, TC, and TO cover classes). Riprap and flow deflectors are the dominant cause of those restrictions. Coincident with riparian habitat extent, the majority of restricted riparian polygons occur within partially confined and unconfined channel types, characterized by braided and multiple channels (Figure 4-128).

By way of comparison, Skagen et al. (2001) reported that the effect of extensive bank stabilization (28 percent of total bank length) in the upper Yellowstone River (Park County or Region PC) resulted in a loss of habitat functionality, which affected a range of aquatic and terrestrial wildlife using those habitats (Auble et al. 2004).

[3] Areas of the natural Channel Migration Zone (CMZ) that have become isolated from the active migration corridor by physical features such as bank armor.

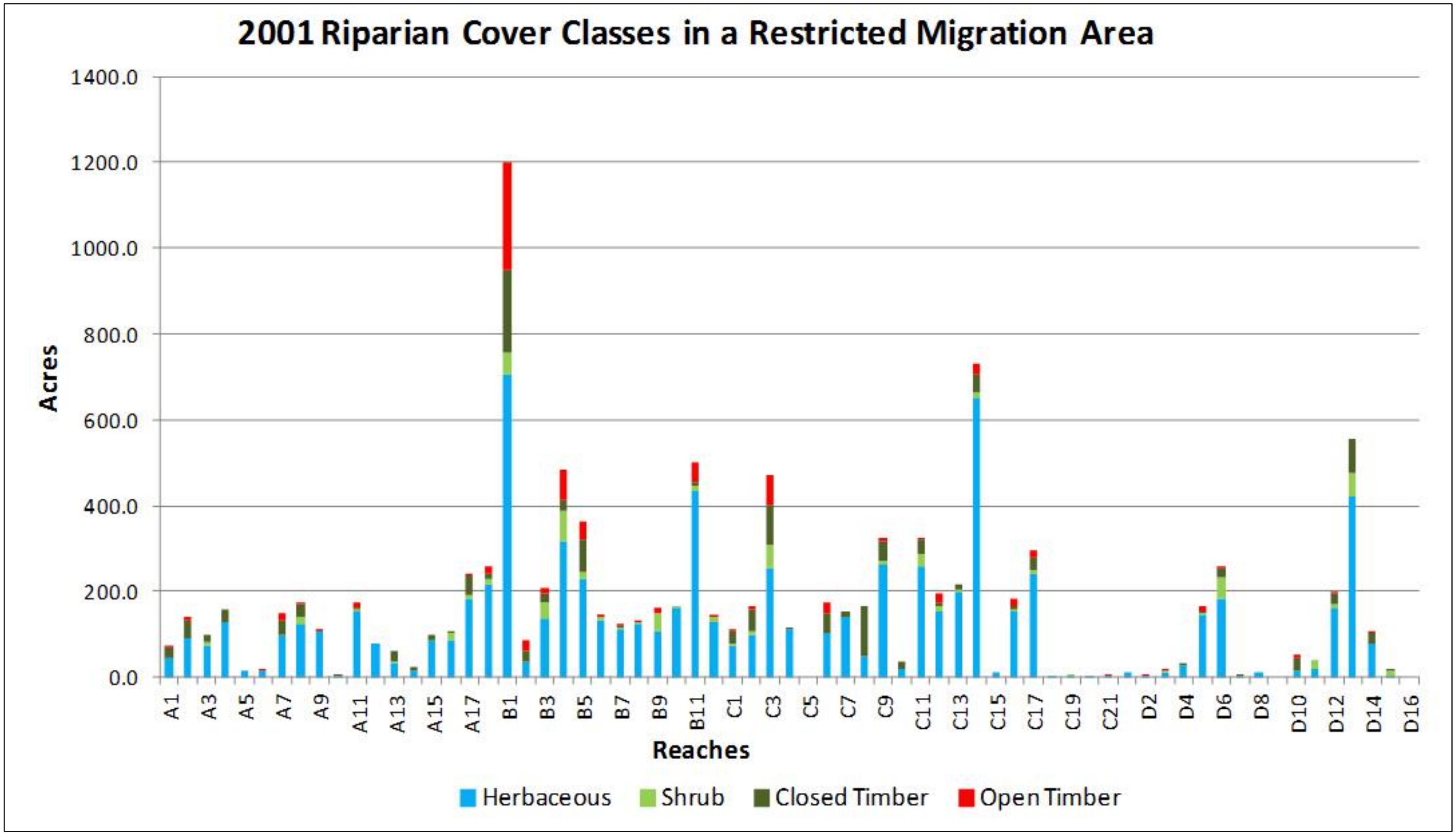


Figure 4-127 Riparian cover classes affected by Restricted Migration Areas (RMAs)
Note: *The herbaceous class is the riparian cover class most affected*

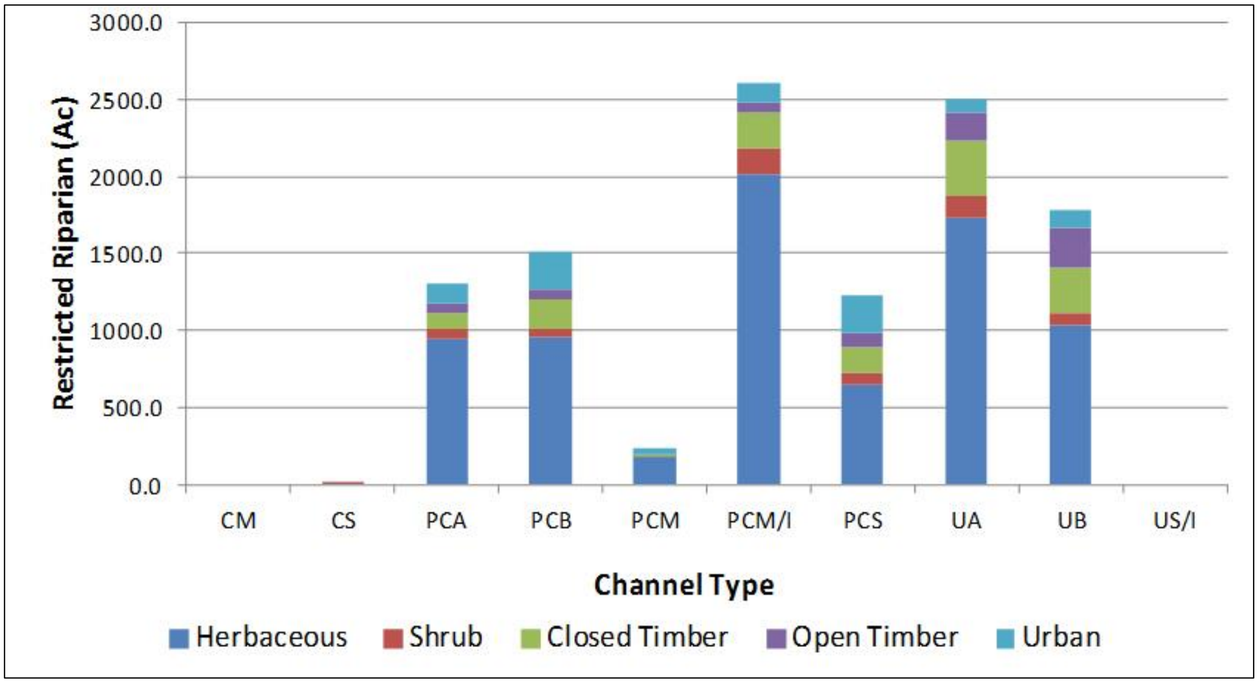


Figure 4-128 Channel type of riparian habitat within RMAs

Note: *Majority of isolated riparian habitat is within one of the less confined channel types. Less confined channel types are more likely to have bank protection features installed there*

Channel migration is also a source of significant change of 1950s riparian cover. Dynamic equilibrium operating in healthy river systems maintains relatively equal proportions of riparian and channel habitat over the long term. In Park County, Merigliano and Polzin (2003) estimated that losses to natural succession were responsible for twice the loss of riparian habitat converted to agricultural uses. In regions A–D, however, the net loss of riparian cover to agriculture and other land uses has been masked by the gain in riparian cover over time due to riparian recovery in abandoned side channels in regions C and D.

These results are consistent with the overall trends reported by Merigliano and Polzin (2003) for the Park County study area (Upper Yellowstone River). They found that reaches with braided channel classifications showed an increase in older cottonwood stands, in addition to an increase in the presence of gravel bars. In reaches with moderate confinement, they also noted an aging of cottonwood stands and a reduced abundance of gravel bars. They concluded that the river is presently less dynamic with reduced regeneration of cottonwoods and mature forest stands becoming decadent without replacement by younger woody age classes. They did not present a clear reason for the reduced river dynamics, but suggested that human activities, including agriculture and bank stabilization, may have contributed, as well as factors like climate change and alterations to the sediment-loading regime.

Following are the primary findings related to riparian migration restrictions:

- Riparian recruitment and succession is directly related to active channel migration, with greater extent and density of riparian habitats occurring within reaches having less channel confinement (see Figure 4-129).

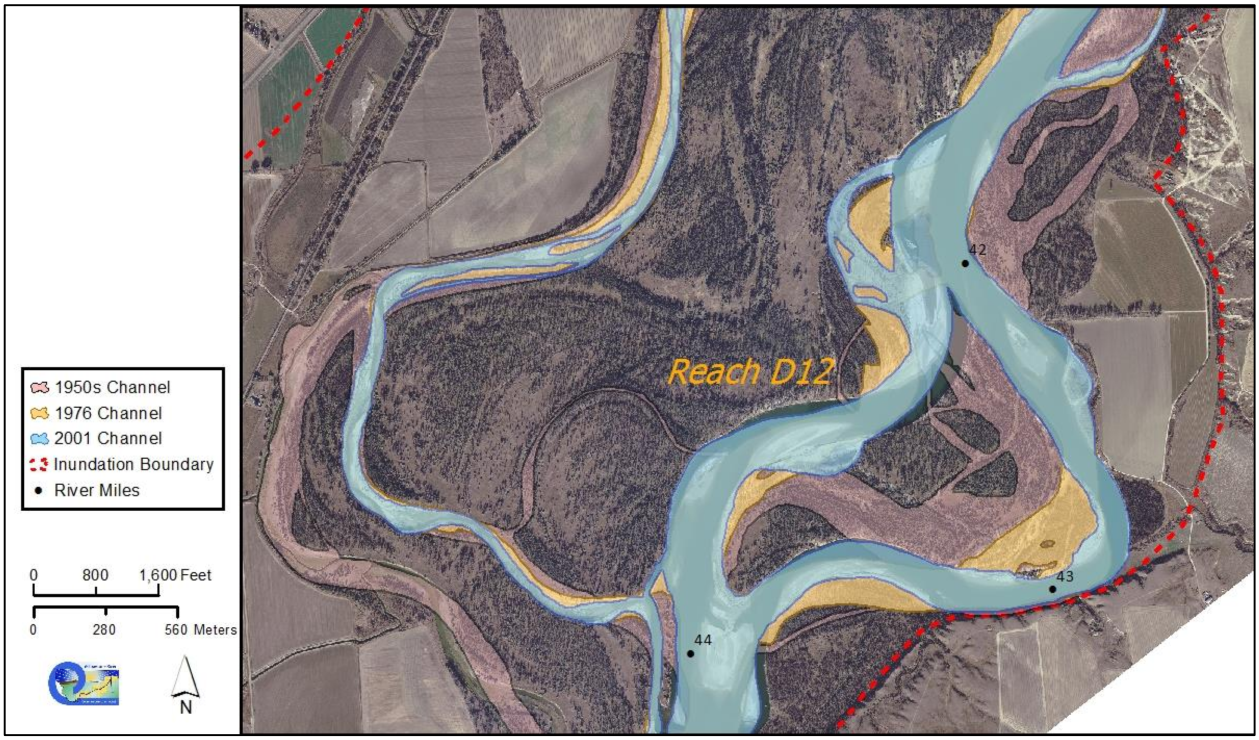


Figure 4-129 Channel Migration and Riparian Recruitment

- Channel migration restrictions affect about 11,000 acres of riparian habitat or about 7 percent of all riparian habitats. The Herbaceous class of riparian habitat is the main category affected.
- Rock riprap and related flow deflector installations are responsible for over 70 percent of the migration-restricted riparian area.
- Regions B and C contain the majority of riparian Restricted Migration Areas (RMA).
- Overall net losses in riparian cover due to conversion to other uses since 1950 have been masked by increases in riparian succession occurring in abandoned and blocked side channels in regions C and D.
- Many riparian areas affected by floodplain isolation are also impacted by channel migration restrictions, making them even more susceptible to reduced function and causing further impairment of the ecological services they once provided.

4.7.8 Summary of Agricultural Impacts—Irrigation

No specific studies were undertaken as part of the CEA or available in the scientific literature to help quantify or qualify the impact of irrigation withdrawals or return flows in the Yellowstone corridor on riparian extent or hydrology. It must be assumed that, based on anecdotal evidence, the creation of many ponds, canals, ditches, and irrigated fields has led to increased return flows, some of which discharge to riparian areas. Likely, some riparian areas are made wetter while the development of irrigation system infrastructure and irrigated fields has had a negative impact by altering and converting riparian areas to irrigated fields and other non-riparian land uses (see Figure 4-130). As noted in Section 4.2.4, conversion of 1950s riparian habitat to irrigated fields by 2011 consumed some 5,500 acres of riparian cover.

Figure 4-130 A wheat field replaces a stand of Plains cottonwood closed timber riparian habitat

Citations by various authors also provide information showing that irrigation return flows that affect riparian areas in many cases also bring increased sediment along with concentrated agriculture nutrients and chemicals that may be harmful to riparian and wetland ecology and the organisms living there. Some studies have shown increased rates of erosion (Dillaha et al. 1989) and pesticide losses of one to ten percent of that applied (Baker 1985). While sediment, nutrient, and chemical attenuation are recognized functions of riparian areas, the observed accelerated delivery rates from intensively managed cropland often overwhelm riparian processes and lead to a decline in the quality of the environmental services provided by riparian areas (National Academy of Sciences 2002). Section 4.8 provides additional discussion regarding water quality implications of agricultural runoff.

Following are the primary findings related to irrigation impacts:

- Direct conversion of riparian habitat to irrigated agriculture resulted in the loss of about 5,500 acres of riparian cover between 1950 and 2011. Tens of thousands of additional riparian wood and grassland acres were converted prior to 1950, as irrigation systems were developed and expanded along the river corridor.

- No published Yellowstone River irrigation studies are available to provide local data on which to base any analysis. Based on a review of applicable literature, agricultural return flows and seepage may have led to growth in the extent or creation of some riparian and wetland areas; however, accelerated rates of nutrients, sediment, and other pollutants have the potential to reduce riparian health and alter species composition resulting in a net loss of riparian value. As noted in Section 4.8.2, artificially created riparian habitats and wetlands rarely possess the same function or attributes of naturally derived riparian areas and wetlands.

4.7.9 Summary of Agricultural Impacts—Livestock Management

Grazing riparian areas with domestic livestock without consideration of the timing, frequency, intensity, and duration of use has been reported to reduce the complexity, quality, and structure of riparian areas throughout the western U.S. (Armour et al. 1994; Chaney et al. 1990). In general, the decline of shrubs and trees are related to livestock browsing on seedlings and young plants (Clary 1989; Belsky 1999) and to a lesser degree in some locations, rubbing or mechanical damage (Skovin review 1984). Water quality, bank stability, floodwater attenuation and storage, and aquatic and terrestrial wildlife habitat declines have been noted (Poff 2012; National Academy of Sciences 2002; Fleischner 1994). Excessive livestock grazing can lead to infestations of weeds and invasive species and reduced ecological function (Kudray 2005; Belsky 1999; Chaney et al. 1990).

Grazing disturbance tends to produce a more open, herbaceous plant community dominated by upland plant species (National Academy of Sciences 2002) particularly when season-long, domestic livestock grazing is the norm as compared to the intensive but infrequent use by free-ranging wild ungulates (Platts 1981; Kay 1993) noted by early day explorers (Brownell 2006; Confluence 2003; Raynolds 1867; Russell 1921). Typical problems are the degradation of riparian and wetland woody habitat that alters or shifts plant composition; nutrient enrichment; increases in invasive, grass species like smooth brome (*Bromus inermis*), reed canary grass (*Phalaris arundinacea*), meadow foxtail (*Alopecurus pratensis*), and Kentucky bluegrass (*Poa pratensis*); and decreased soil cover (Knight et al. 2014).

Although many authors question the suitability of any grazing in riparian areas (Mehan and Platts 1978; Ohmart 1996), there have been reports published more recently that indicate grazing systems using scientifically based prescriptions for livestock grazing frequency, duration, and intensity may mediate negative impacts. Specifically, their studies have shown that managing livestock to avoid overuse by implementing seasonal grazing, rest-rotation, deferred grazing, and high intensity-low frequency grazing systems can result in riparian zones regaining cover and function over time (Erhart and Hansen 1998; Armour et al. 1994; Elmore and Kauffman 1994; Savory 1998). Extremely damaged riparian systems may require very long periods of rest in order to fully recover function (Skovlin 1984; Elmore 1996; Clary et al. 1996) or, to guarantee full recovery in extreme cases, permanent protection from all grazing may be required (Chaney et al. 1990; Bock et al. 1993; Case and Kauffman 1997).

No extensive dataset, gathered in a systematic way that measures and evaluates riparian health or condition or the impact of stressors such as grazing, is available for the entire Yellowstone River corridor. Jones (2014) noted observations that the main drivers of fragmentation and loss of riparian forest habitat quality were (1) bank armor, (2) riparian conversion (agriculture), and (3) poor riparian management (unregulated livestock grazing). In a more focused study, Eggers (2005) looked at the impact of cattle grazing at 27 paired, grazed/ungrazed locations along the river corridor between Emigrant, Montana, and Sidney, Montana. Her comparison found that the grazed sites exhibited a general decline in plant litter; and native woody, forb, and graminoid species diversity and production, with a commensurate increase in bare ground and nonnative species cover. Invasive species were present in both grazed and ungrazed riparian communities. Boggs (1984) looked at riparian community succession in the lower Yellowstone River and the impacts of altered hydrology, fire, and logging, but did not evaluate grazing as a modifier of riparian community succession.

Following are the pertinent findings related to livestock grazing impacts on riparian habitats:

- While only limited riparian community studies specific to the Yellowstone River are available from which to draw detailed conclusions regarding riparian health and response to grazing, pertinent literature and recorded observations indicate that season-long, livestock grazing results in reduced native riparian species diversity, community composition, and structure, and facilitates invasion by nonnative, invasive species.

- Grazing-related alterations to riparian communities may also affect the function of the local terrestrial and aquatic ecosystems.

- Prescribed livestock grazing practices are reported to result in altered riparian zones regaining cover and function when livestock are managed over the long-term to avoid overuse. But in extreme cases, permanent exclusion from grazing may be required to restore function.

- Focused field studies are needed to better define the scope and impact of various livestock grazing practices on riparian habitat quality and quantity in the Yellowstone River corridor.

4.7.10 Russian Olive

Russian olive is designated as a regulated noxious weed in Montana (Pick 2013; see Figure 4-131). The species is an incidental plant community type in all regions (Hansen et al. 1995). It has the potential to develop into a thick, nearly impenetrable community on sites with spring moisture and slightly alkaline soil (Lesica and Miles 2001). It is also can invade mature cottonwood stands since it is tolerant of shade. Russian olive seed lasts decades and the plan flourishes in slightly wet, saline sites where livestock and wildlife do not browse extensively on the thorny vegetation (Center for Invasive Species Management 2014).

Figure 4-131 Russian olive removal activities

Russian olive also is tolerant of shade as well as growing in direct sunlight (Nagler et al. 2009). It also may alter the habitat to the point at which other exotic organisms are attracted and flourish, which degrades the environment for native wildlife species either through increased competition or parasitism (Lesica and Miles 2001). In some situations, Russian olive may preclude or compete with regeneration or growth of native species, thereby altering the species composition and structure of riparian habitats. Grazing by livestock is practically prohibited by dense infestations.

The greatest extent of Russian olive, depicted in Figure 4-132**,** is in Region C with 2,475 acres—or about 0.13 percent of the region's total area (46,000 acres) and 54 percent of the total infested area in all regions (Combs and Potter 2011; DTM 2013). Their extent is related to the relatively wide floodplain and footprint of Region C. When normalized on a percentage of area basis, Region B has the greatest concentration of Russian olive with about 0.3 percent of its area occupied by the species. Russian olive is dramatically reduced in density in reaches above A15 near Park City. Russian olive extent and density appears to increase in a downstream direction through Region C but declines in Region D. Overall, the analysis of Russian olive extent and frequency is somewhat skewed by the presence of linear features such as irrigation ditches and canals, surface drains, and fences, as well as by the presence of tributary floodplains (DTM 2013).

Russian olive within the river corridor occurs more frequently on moderately confined channel types, with over 30 percent of all Russian olive located within PCM/I channel types with islands well occupied by the species. Islands that have existed since the 1950s are even more favored with occupation percentages above 5 percent for many reaches in Region B and especially Region C. Russian olive occurs more frequently within the Shrub and Closed Timber categories of riparian cover (Figure 4-133).

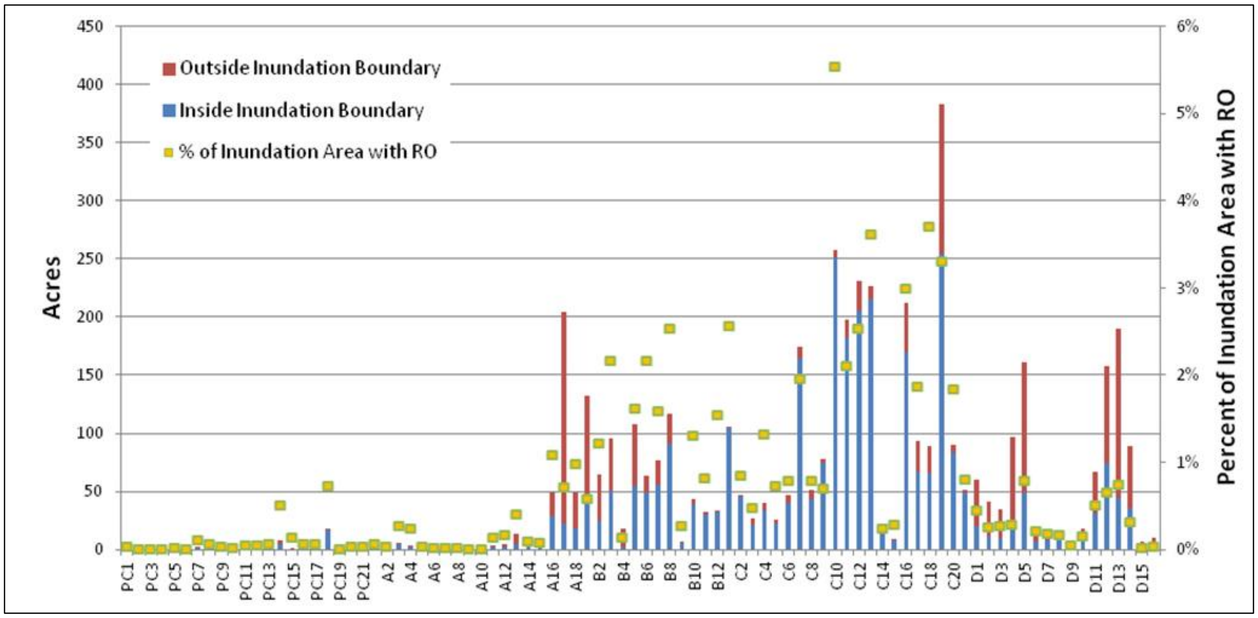


Figure 4-132 Russian olive presence (2008) in relation to the 100-year inundation boundary by reach

Note: *The percent of the inundation boundary occupied by Russian olive is also shown on the right side axis (DTM 2013)*

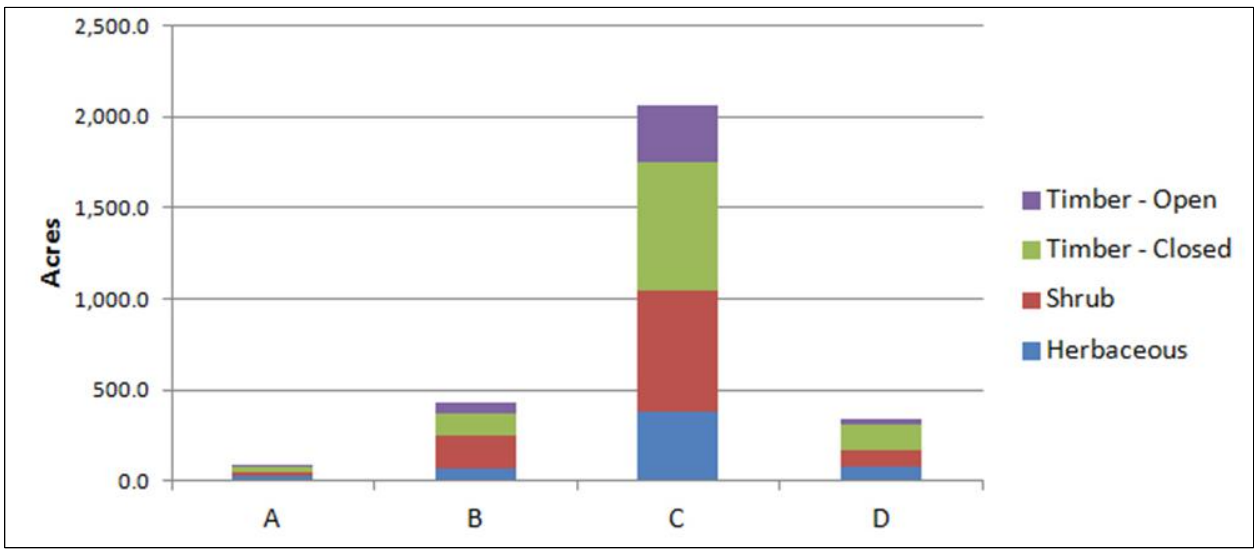


Figure 4-133 Russian olive distribution within 2001 riparian cover in regions A–D

A majority of Russian olive acreage occurs outside of the Channel Migration Zone (CMZ), but of the Russian olive within the CMZ, it demonstrates a preference for near channel locations within the 100-year inundation zone (DTM 2013). The extent of Russian olive mapped within the Closed Timber category may have been underestimated in some places due to the mapping procedure used and difficulty in identifying the species under dense overstory foliage (DTM 2013).

Implications are that Russian olive—along with saltcedar—can perhaps cause channel narrowing, island building, and simplification of complex channel patterns due to restricting channel movement and trapping sediment, as has been observed in the southwest U.S. (Bankhead et al. 2008; Everitt 1998; Graf 1978). It is not known whether those channel modifications are presently occurring or are likely to occur on a large river system like the Yellowstone River, but in practice, Russian olive and saltcedar are more invasive on hydrologically controlled, less dynamic river systems (Lesica and Miles 2001). Additional study of this potential phenomenon is recommended.

4.7.10.1 Saltcedar

Saltcedar is an invasive species and noxious weed that occurs as an incidental community type more frequently in regions C and D and less so in regions A and B. Saltcedar typically occurs as homogenous stands on sites with higher salt concentrations. Saltcedar favors bare, moist, slightly saline soil found on shorelines, islands, and point bars where it quickly develops an extensive root system (Nagler et al. 2009; Sher et.al. 2001). Once mature, the plant produces seed continuously during the growing season. The combination of shed leaves containing high levels of salt and dense vegetative growth often result in a thick, monotypic stand of saltcedar with bare ground beneath (Pick 2013; Jacobs and Sing 2007). The plant's genetic diversity may allow saltcedar to rapidly acclimate to colder climates and facilitates its spread to higher elevation sites (Sexton et al. 2002).

The implications of saltcedar infestation on riparian plant communities are similar to those for Russian olive, but with very limited quantitative data available on saltcedar distribution across the Yellowstone River corridor, little can be added to the narrative with respect to the scale or scope of the impacts. As with Russian olive, most local County Weed Districts along the Yellowstone River have targeted saltcedar and made identification and control a priority, but more remains to be done. Additional study and monitoring of saltcedar spatial distribution and frequency in riparian communities are recommended so that future control efforts can be effectively prioritized and evaluated.

4.7.10.2 Other Invasive Species

Because riparian habitats are created and destroyed through the processes of erosion and sedimentation (Knight et al. 2014; Merigliano and Polzin 2003; National Academy of Sciences 2002), these fluvial processes also render the freshly disturbed sites very susceptible to invasion by numerous exotic species. Jones (2001) noted that hounds tongue (*Cynoglossum arvense*), Canada thistle (*Cirsium arvense*), leafy spurge (*Euphorbia esula*), and spotted knapweed (*Centaurea maculosa*) are serious pests that threaten riparian habitats along the Yellowstone River. A number of other adapted invaders have moved to nearby watersheds and threaten the Yellowstone River Basin (Montana Weed Control Association 2014). Eggers (2005) found that invasive species were more prevalent in degraded, grazed riparian areas than in ungrazed riparian areas. Impaired riparian functions and values result if invasive weeds are allowed to spread uncontrolled (National Academy of Sciences 2002). Vigilance and landowner education is recommended to prevent infestation or expansion of these and other invasive species in the Yellowstone River watershed.

Common buckthorn (*Rhamnus cathartica*) is another invasive shrub that occurs in random locations within cottonwood forest communities along the lower Yellowstone River (Pick, pers. obs. 2014; Lesica 2012). The plant's presence is likely the result of ornamental use in areas near the river corridor and has the potential to become widespread like Russian olive and saltcedar. It is listed as a noxious weed in a number of upper Great Plains states (Center for Invasive Species Management 2014). (See http://mtweed.org for more information on identification and control of noxious weeds in Montana).

Following are the pertinent findings related to invasive species impacts on riparian habitats:

- The presence of large numbers and high densities of invasive species is an indication of reduced riparian health. Invasive vegetative species compete with native plants for light, space, and nutrients, thereby diminishing the vigor, growth, and diversity of native plants.
- No temporal evaluation of invasive species distribution and occurrence in the Yellowstone corridor is possible given a lack of historical data.
- Russian olive occupies about 3,000 acres of the 100-year inundation area. Other metrics related to that species are:
    - Russian olive extent increases in a downstream direction from regions PC through C. Reasons for the decline in extent in Region D are not clear but may be related to the intensity of agriculture in that region.
    - Its expanse is greatest in Region C, but it occurs at higher density in Region B.
    - It occurs most frequently in the Shrub and Open Timber, in that order.
    - Russian olive occurrence is correlated to less confined geomorphic reaches with braided channels and islands (PCM/I). About 10 percent of abandoned channel and island areas in Region C are infested with Russian olive.
- Russian olive and saltcedar appear to have a competitive advantage over native species in occupying near-channel sites. There is not sufficient science available from which to draw conclusions, but the possibility exists that their prevalence there could affect channel migration and morphology due to the density and strength of their root mass compared to mature cottonwoods.
- No temporal or spatial analysis of saltcedar is possible due to a lack of historical data, but anecdotal evidence indicates that it is widespread within the middle and lower regions of the river.
- Genetic diversity in saltcedar facilitates its adaptation to colder, higher elevation climates.
- Many additional invasive species are poised to invade the Yellowstone River watershed. Individual county weed district control and outreach approaches are in place and appear to be working with varying levels of success. A coordinated mapping and control monitoring approach is needed, however, to guide future efforts to target invasive species.

4.7.11 Other Potential Impacts on Riparian Systems

As described in the preceding sections, there are a number of notable, indirect human influences on riparian areas within the Yellowstone River corridor. Based on the available studies and related literature, they are thought to be the most important sources of riparian alteration or change. Given the scarcity of Yellowstone-specific studies with quantitative and qualitative data to provide context, other less well-researched issues could contribute to riparian impacts in the future. This section describes some of them.

4.7.11.1 Climate Change or More Variability in Extremes

As discussed in detail in Section 4.3.4.4 Hydrology, potential impacts of historical and projected climatic trends on the Yellowstone River are complex and have not been analyzed in detail, but suggested modeled climate changes could potentially affect the river's riparian habitat in several ways. Due to their topographic position and dependence on water resources, riparian and wetland systems may be impacted as much as any other river-related resources by changes in water availability, duration, or timing that are driven by variability or extremes in climate. At a minimum, warmer air temperatures are projected to lead to reduced snowpack, earlier snowmelt runoff and elevated water temperatures, particularly affecting summer low flows (Chang and Hansen 2014; Leppi et al. 2012; Miller et al. 2008).Continued trend in the reduction in streamflow during runoff events or low-flow periods would be expected to further stress riparian areas and lead to impaired function due to exposure to longer, warmer dry periods (Knight et al. 2014). Susceptibility to invasive species could be enhanced as well (Hellman 2008). Alteration of flooding duration and even low-flow regimes has been shown to be a very significant modifier of riparian community composition and extent (Scott et al. 1997; Auble et al. 1994), so any further reductions in this aspect of minimum ecological flows necessary to sustain the riparian resource could have significant impacts (Braatne et al. 2007; Reily and Johnson 1982). Potential effects of climate change are discussed here to provide a basis for planning future water use and conservation efforts and to ensure sufficient consideration is made of riparian and wetland system requirements.

Fire and beaver are also recognized historical modifiers of riparian mosaics that no longer have a significant impact under present policies and practice along the Yellowstone River (Boggs 1984). Future trends in longer, more arid summers could affect the frequency of wildfire. A shift in how beavers are viewed by landowners would be needed to restore significant numbers of the animals to the Yellowstone River corridor (Pick, pers. observation). As a result of constraints in time and financial resources, specific climate projections and analyses have not been conducted under the auspices of the Yellowstone CEA, but are encouraged to be undertaken as resources are available by those who follow this work.

4.7.11.2 Municipal and Industrial Water Use

Municipal and industrial water users are relatively minor users and even smaller consumers of water based on overall water withdrawals on the Yellowstone River. Compared to agricultural withdrawals, municipal water use in counties along the river is relatively minor, making up just over 1 percent of the daily water use. Industrial water use is somewhat greater, but comprises only about 4 percent of the total water use. However, it was also noted that off-channel industrial uses (oil extraction, mining, and energy production) consume water in the lower river, which could have impacts on flow stage during low-flow periods.

With projected increases in population and industry within the Yellowstone River watershed (mining, oil, and gas development), increased water demand will occur in the future which would heighten the impact of total water withdrawals during low-flow periods, particularly when coupled with possible climate change or variability. Data or metrics for this analysis and potential impacts on riparian areas have not been made but would be expected to parallel the subjective reasoning in the preceding sections.

4.7.11.3 Urban/Exurban Development

The majority of past conversion and alteration of riparian habitats has been related to agriculture, primarily because of the dominant spatial extent of agricultural land uses in the basin and corridor. While agricultural land uses will likely not expand greatly in the future, it is expected that urban and exurban land uses will continue to expand as the population grows within the corridor. Current laws and regulations (e.g., Clean Water Act (CWA), Montana Stream Protection Act of 1963, 1975 Natural Streambed and Land Preservation Act, and 1973 Montana Floodplain and Floodway Management Act) could serve to protect riparian environments to some degree; however, continued growth will bring pressure to convert land for housing and urban/exurban infrastructure. Future impacts of urban/exurban development could be significant near urban centers like Billings, Glendive, and Miles City, where riparian and wetland habitat loss has been documented, unless additional programs or policies are instituted to conserve riparian habitat within the river corridor.

4.7.11.4 Changes in Water Quality

The documented reductions in low flow discharge (Section 4.3 Hydrology) on the Yellowstone below the Clarks Fork River confluence, coupled with other potential increases in water demand, could further reduce low flows, especially in the lower river below the Bighorn River confluence. Further reductions in flow have the potential to increase concentrations of water quality contaminants as described in chapter 4.6 Water Quality to a point that beneficial uses could be threatened. Increases in salinity, dissolved solids, nutrients, water temperature, and other water quality metrics have been shown to adversely impact native riparian species establishment and growth (Dillaha et al. 1989). As a result, alteration of species composition, stand structure, and increased susceptibility to invasion by exotic species tolerant of elevated levels of salt and nutrients are potential impacts of water quality changes on riparian and wetland habitats.

The main conclusions reached regarding other impacts on riparian habitats are:

- The limited availability of Yellowstone-specific studies regarding the scope and scale of projected climate change does not allow much to be concluded as part of the CEA other than continued trends in the reduction in the extent and timing of discharge will only exacerbate impacts that diminish or degrade riparian habitat regardless of cause.

- Increased future water use by domestic and industrial sources of water will place added stress on riparian habitat in reaches that have already incurred impacts due to isolation, channel migration restriction, irrigation water withdrawals, and hydrologic alteration.

- Further reductions in the quantity and timing of streamflow have the potential to increase concentrations of water quality contaminants that potentially can alter species composition, stand structure, and increase susceptibility to invasion by exotic species tolerant of elevated levels of salt and nutrients.

4.8 Biology: Aquatic Plants (Wetland Systems)

4.8.1 Introduction

Wetlands perform a variety of important ecosystem services: floodwater and flood energy attenuation, carbon storage, reduction of waterborne pollutants, and habitat for a rich diversity of plants and animals (see Figure 4-134 through Figure 4-136). Wetlands make up only 4 percent of the land cover within the Yellowstone's 100-year inundation boundary (USFWS 2014) but as little as 0.5 percent in Montana (Skagen et al. 2001). Depending on location and elevation, healthy wetlands and riparian areas can store up to three acre-feet of floodwater per wetland acre (U.S. EPA 2006). Fifty-five percent of 245 breeding avian species utilize riparian forests in Montana. Riparian areas support at least 56 percent of Montana's mammals year-long or seasonally, while streamside buffers and wetlands provide habitat for 16 native amphibians, three species of turtles, and seven snake species. Over half of all Montana's wildlife species frequent riparian areas, while 196 terrestrial species are considered riparian or wetland habitat obligates (Ellis 2008).

Figure 4-134 A diverse mosaic of riparian and wetland cover provides excellent wildlife habitat adjacent to the Yellowstone River in Stillwater County (Region A)

Note: *The palustrine emergent wetland[4] in the foreground is interspersed with palustrine scrub/shrub (PSS) habitat. Note that Russian olive occurs on somewhat drier sites within the complex. The riparian cottonwood forest is likely too high and dry to be considered a palustrine forest wetland (PF), if it is not regularly flooded.*

[4] The Cowardin wetland classification system (Cowardin et al 1979) defines palustrine wetlands as non-tidal wetlands dominated by trees, shrubs, persistent emergent, and such wetlands that occur in tidal areas where salinity is less than 0.5 parts per thousand. The emergent, scrub-shrub, and forested subcategories refer to the dominant vegetation type present in the wetland. Riverine wetlands are defined as wetlands associated with a river channel. Riverine wetlands are considered non-vegetated, by definition having less than thirty percent vegetative cover.

Figure 4-135 Bands of riparian and wetland vegetation parallel the Yellowstone River to create a complex pattern of habitat types in Rosebud County

Figure 4-136 Islands between braided channels provide sites for palustrine and riverine wetland habitat at Elk Island Wildlife Management Area (Reach D11)

This section describes human influences affecting aquatic plant communities or wetland systems within the Yellowstone River corridor. Appendix 7 (Aquatic Plants (Wetland Systems)) contains a comprehensive summary of the supporting documentation for wetland systems, as well as a detailed discussion of analyses performed in support of the Cumulative Effects Analysis (CEA). Spatial and temporal alterations to wetland systems, as well as the extent and magnitude of those impacts are described, as appropriate, along with analysis and discussion of the potential sources of those changes.

Wetlands and riparian areas are often considered to be ‘keystone’ habitats in that their relatively small spatial extent provides significant environmental benefits to a much greater area. Given this important circumstance, loss or alteration of wetlands can have serious consequences for the environmental stability of the Yellowstone River ecosystem.

This section addresses alterations to wetland systems by focusing on specific human influences: land use change, off-corridor impacts - hydrologic alteration, transportation infrastructure, agriculture, urban/exurban development, and invasive species. As noted earlier in the discussion of riparian habitat impacts, the quantification of wetland impacts is also based on the 100-year inundation zone (floodplain) product that preceded the 2011 hydraulic and hydrologic modeling and use of the regulated/unregulated flooded area. The 100-year inundation zone, as used here and in the wetland chapter, refers to the area inundated by a 100-year flood without regard to dikes and levees in the floodplain. It was developed to assist with the Cumulative Effects Analysis (CEA) prior to when the later hydraulic and hydrologic analyses were completed by the Corps and USGS (Corps of Engineers 2011; Chase 2013, 2014).

Palustrine and riverine wetlands mapped under the National Wetland Inventory (NWI) procedures (USFWS 2014) within the Yellowstone River corridor were evaluated and tabulated within the 100-year inundation boundary by DTM Consulting, Inc. (unpublished data). Only palustrine and riverine wetland types were evaluated under the CEA. Other wetlands mapped under the NWI program within the corridor such as lacustrine and related types were not considered within this evaluation as their origin and maintenance are generally not related to channel processes. The DTM tabulation condensed NWI wetland categories into four CEA wetland categories: riverine, emergent, scrub-shrub and forested. Readers should note that riverine wetlands are considered non-vegetated, by definition having less than thirty percent vegetative cover. The analysis found that wetlands are widespread throughout the corridor, but not equally distributed in kind and amount. Wetlands are arrayed in a complex, non-linear pattern within the study area.

Table 4-16 provides a summary of the human influences described in this section, along with the associated impact, spatial extent of that impact, and relative magnitude of the impact. Figure 4-137 and Table 4-17 depict the relative extent of wetlands within the Yellowstone River 100-year inundation boundary as of 2006. Wetland acres within each region and reach were normalized by valley mile to facilitate direct comparison of relative extent or density.

Table 4-16
Summary of Human Impacts on Yellowstone River Wetland Systems

Human Influence	Impact on Wetland Systems	Spatial Extent	Relative Impact to Wetlands
Land Use Change	Conversion to other land uses – primarily irrigated agriculture	System-wide	Major
Off Corridor Impacts: Altered Hydrology on Bighorn River (Yellowtail Dam)	Reduced peak flows that replenish wetland energy regime	Below Bighorn	Major
	Reduced summer low flows alter local water table making wetlands more susceptible to invasive species	Below Bighorn	Major
	Reduced channel forming/changing flows lower wetland recruitment and simplify wetland complexity over time	Below Bighorn	Major
Floodplain Isolation due to fills, dikes and levees.	Isolation of wetlands from channel and floodplain	Limited extent system-wide, but more pronounced in specific reaches	Moderate
Channel Restrictions due to bank stabilization activities	Long-term reduced channel migration and wetland formation	Limited extent system-wide, but more pronounced in specific reaches	Locally major
Agriculture - Irrigation	Return flows, conveyance seepage, and impoundments increase/maintain wetland area but with uncertain value	System-wide, but more pronounced in lower river	Variable
Agriculture – Livestock Management	Simplification of habitat and possible nutrient enrichment/facilitate invasion by exotic species	System-wide	Moderate to major depending on management
Invasive Species	Change to structure and species composition of wetland communities affects function	System-wide	Major
Climate Trends	Reduced August Low Flows and Warmer Temperatures May Make Wetlands More Vulnerable to Invasive Species	System-wide	Uncertain but if recent trends continue, impact is rated slight in the short-term and moderate in the long-term
Municipal/ Industrial Water Use	Potential for reduced low flows	Near urban and resource development	Uncertain, dependent on growth
Urban/Exurban Development	Potential for increased development pressure with population growth	Near population centers	Uncertain, dependent on growth
Change in Water Quality	Potential impacts to wetland recruitment and vegetative community composition	Mid-to lower river	Minor
Transportation Impacts	Potential impacts to wetland adjacent to existing roadways and new roads	System-wide	Minor

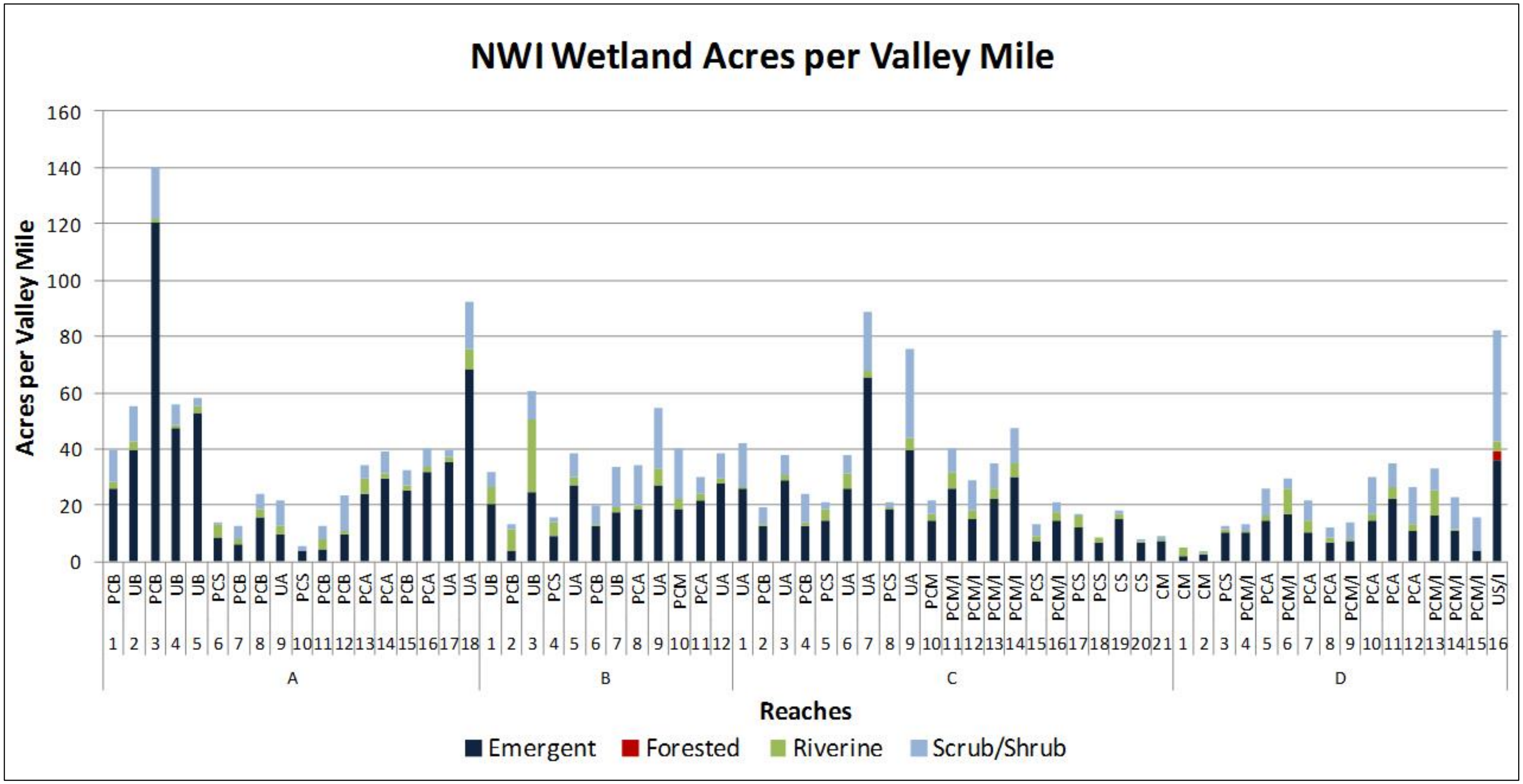


Figure 4-137 NWI Wetland types expressed as acres per valley mile to show relative extent or density
Note: *Geomorphic reach types are also shown to depict the relation of greater wetland density to less confined reach type where reaches with multiple, braided or Anabranching channels have the greatest density of wetlands per valley mile. (See Table 3-2 for explanation of channel type abbreviations)*

Table 4-17
Density or Relative Extent of Wetlands in All Regions of the Yellowstone River 100-year Inundation Zone

CEA Region ID	Total Wetlands (Acres)	Valley Length (Miles)	Wetland Acres/Valley Length (Miles) Mean	Wetland Acres/Valley Length (Miles) Minimum	Wetland Acres/Valley Length (Miles) Maximum
PC	2,478	76.6	32.4	0.0 (PC1)	121.2 (PC18)
A	3,135	86.0	36.4	5.6 (A10)	140.3 (A3)
B	2,486	74.6	33.3	13.6 (B2)	60.9 (B3)
C	3,935	124.6	31.6	7.7 (C20)	88.9 (C7)
D	2,990	128.3	23.3	3.9 (D2)	82.4 (D16)

NWI wetlands total about 12,716 acres in Regions A to D. The most extensive wetland type by far is palustrine emergent wetlands (8,011 acres or 63 percent) and the second most extensive is palustrine scrub/shrub (3,458 acres or 27 percent). Riverine sites constitute about 10 percent of the total mapped wetland area. Region A has the greatest relative extent or density of wetlands with 36 acres per valley mile of wetlands present. Reach A3 has the greatest extent of any one reach with 140 acres per valley mile. Region D has the fewest wetlands present with Reach D2 having only about four acres per valley mile. Forested wetlands are the most rare type occurring only twice on 22 acres in Reach D16 and at the Confluence with the Missouri River.

For purposes of comparison, Park County (Region PC) contains about 2,500 acres of riverine and palustrine wetlands within the 100-year inundation zone with the majority (47 percent) in the palustrine emergent category. Notably, forested wetlands made up about 19 percent of total wetlands mapped in Park County while the scrub-shrub category comprised 29 percent. The Park County region also shows great variation between reaches going from no wetlands acres within the 100-year inundation zone in Reach PC1 to over 120 acres per river mile. The sizeable difference in the presence of forested wetlands in Park County compared to Regions A-D may be due to differences in mapping protocols as much since geomorphic differences as two separate mapping efforts were involved.

4.8.2 Summary of Land Use Conversions

The magnitude of direct wetland conversions within the Yellowstone River corridor over time cannot be measured since it was not possible to accurately delineate the historical wetland extent using imagery as was done for the temporal riparian inventory. Complicating matters, many floodplain wetlands by nature are ephemeral, lasting only years to decades before they are replaced by channel movement. However, the direct conversion of wetlands, similar to that observed for riparian habitat, has likely been significant over time in the Yellowstone River corridor. The primary conversion of historical wetland habitat within the Corridor is assumed to be conversion to agriculture, transportation, and urban/exurban land uses during settlement and development due to their dominant presence within the corridor today.

Early records and historical documents indicate that the pre-settlement (early 1800s) Yellowstone River corridor supported abundant stands of cottonwood and other woody species throughout the project area except where the floodplain was restricted (Confluence Consulting 2003). Some estimates suggest that Montana has lost a quarter to more than one-third of its original wetlands to fill or drainage (MDEQ 2013; Dahl 2010). A study of Reaches A16 and D6 (Kudray and Schemm 2006) estimated that between 1950 and 2001, total wetland acreage declined approximately 354 acres or an average loss of about eight percent. The study also noted that an increase in artificial, freshwater ponds within the corridor (captured within the NWI's Palustrine Aquatic Bed category) masked the actual extent of wetland losses so actual losses have likely been much greater. The value of these artificial wetland features as direct replacement for highly complex, shallow water wetlands is much debated (Dahl 2010). It is reasonable to assume that at least a similar decline has occurred within the Yellowstone River corridor due to the intensity of development that has occurred along the river.

Recent trends in wetland losses have been reduced in recent years due to various laws enacted by Congress and Executive Orders issued to protect wetlands. Primary among these protections is the Clean Water Act (CWA) (33 U.S.C. § 1251 et seq.) which regulates alteration of wetlands adjacent to or on navigable waters of the United States or their tributary systems. Recent proposals to provide greater definition to jurisdictional wetlands under the CWA are pending and likely will remain so for the near future. Due to their proximity and designation as Palustrine wetlands, the wetlands mapped under the National Wetland Inventory (NWI and evaluated within the Yellowstone CEA are considered jurisdictional and therefore have been regulated under the CWA since the 1970s (US Army Corps of Engineers 2014).

4.8.3 Summary of Off-Channel Impacts (Hydrologic Alterations)

The Hydrology section (Section 4.3) documents measurable reductions in May-June flood flows, beginning at Billings with even more pronounced reductions below the mouth of the Bighorn River, which resulted in the isolation of side channels and altered channel morphology. The hydrologic alterations were determined to be due to water withdrawals for irrigation and other uses above the Bighorn confluence and primarily due to operation of Yellowtail Dam and other upstream reservoirs, below the Bighorn. Reduction in late summer streamflow (developed condition) was also identified in the 4.3 Hydrology analyses. Higher base and winter flows were determined to not impact wetland systems to an appreciable degree.

Numerous studies in similar river systems have highlighted the importance of large, peak flows to maintain wetland and riparian extent and health (Rood et al. 2008; Braatne et al. 2007; Kudray and Schemm 2006; Merigliano and Polzin 2003; Scott et al. 1997). The impacts noted above further disrupt wetland systems already affected by channel and floodplain restrictions. Without the changes in channel dimension and pattern brought by channel migration as a result of flood flows (floodplain turnover), wetlands are diminished in spatial extent as well as function due to simplification in vegetation and structure. This impact is well illustrated in the relationship between wetland extent and floodplain turnover. Figure 4-138 depicts this relationship for the Yellowstone River. Reductions in channel migration and floodplain turnover due to hydrologic alterations or other causes will result in reduced wetland recruitment over time. Figure 4-139 depicts the change in inundated wetland area as the result of depleted flows modeled for the regulated two-year flow condition compared to the unregulated flood elevations (see more details in Hydrology Section 4.3).

Changes in late summer low flows are linked to stresses on riparian and wetland systems as the lower discharge level drops the local water table during a period of high plant stress (elevated air temperature and evapotranspiration requirement) making the wetland systems susceptible to infestation by more drought tolerant invasive species. Seasonal wetlands at lower elevations are likely to be impacted the greatest as they are dry for part of the growing season and will dry sooner which will affect species composition.

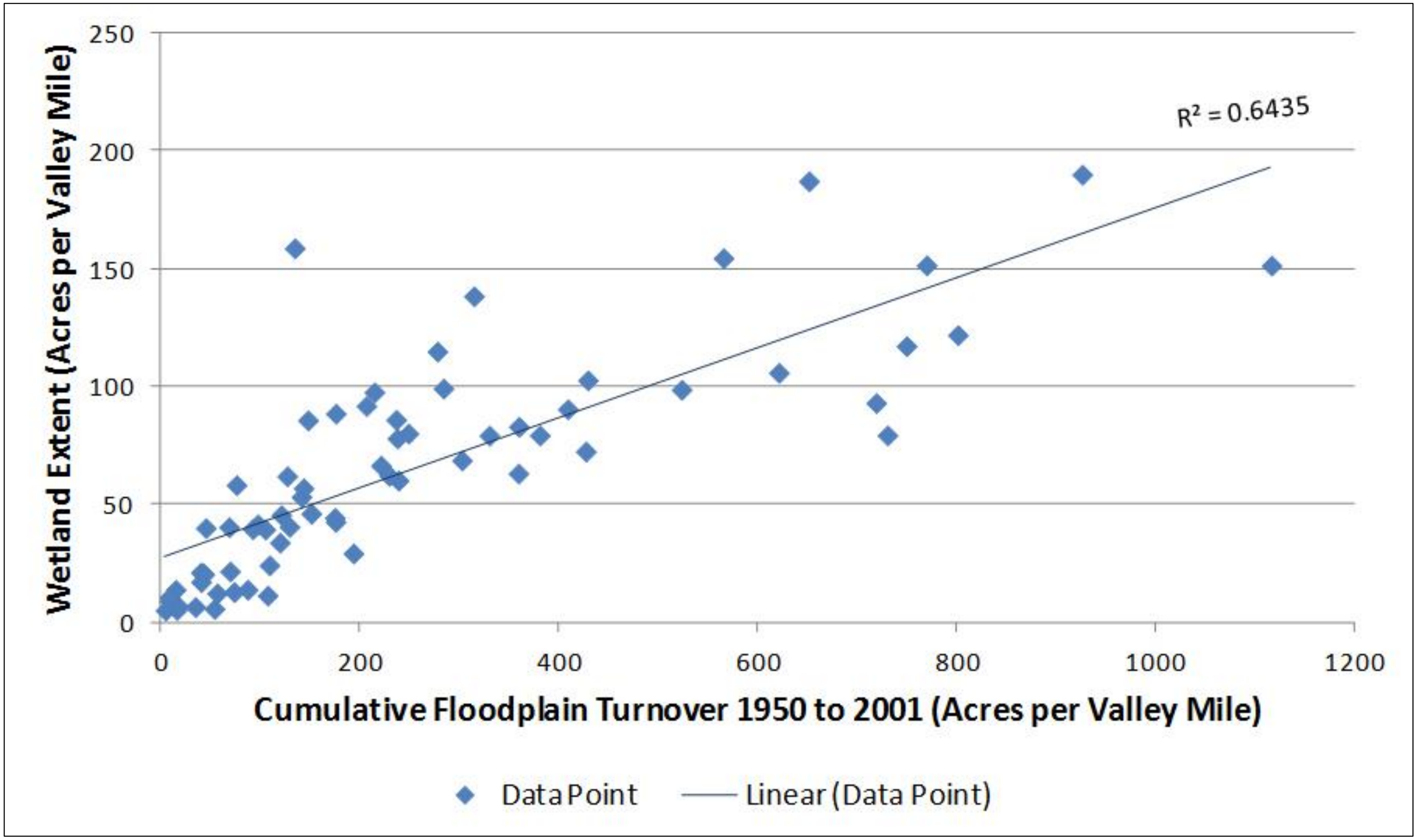


Figure 4-138 Relationship of wetland density to the cumulative floodplain turnover (loss and gains) for all channel types
Note: *Figure shows a definite trend indicating that reaches with higher turnover values generally have relatively higher densities of wetlands.*

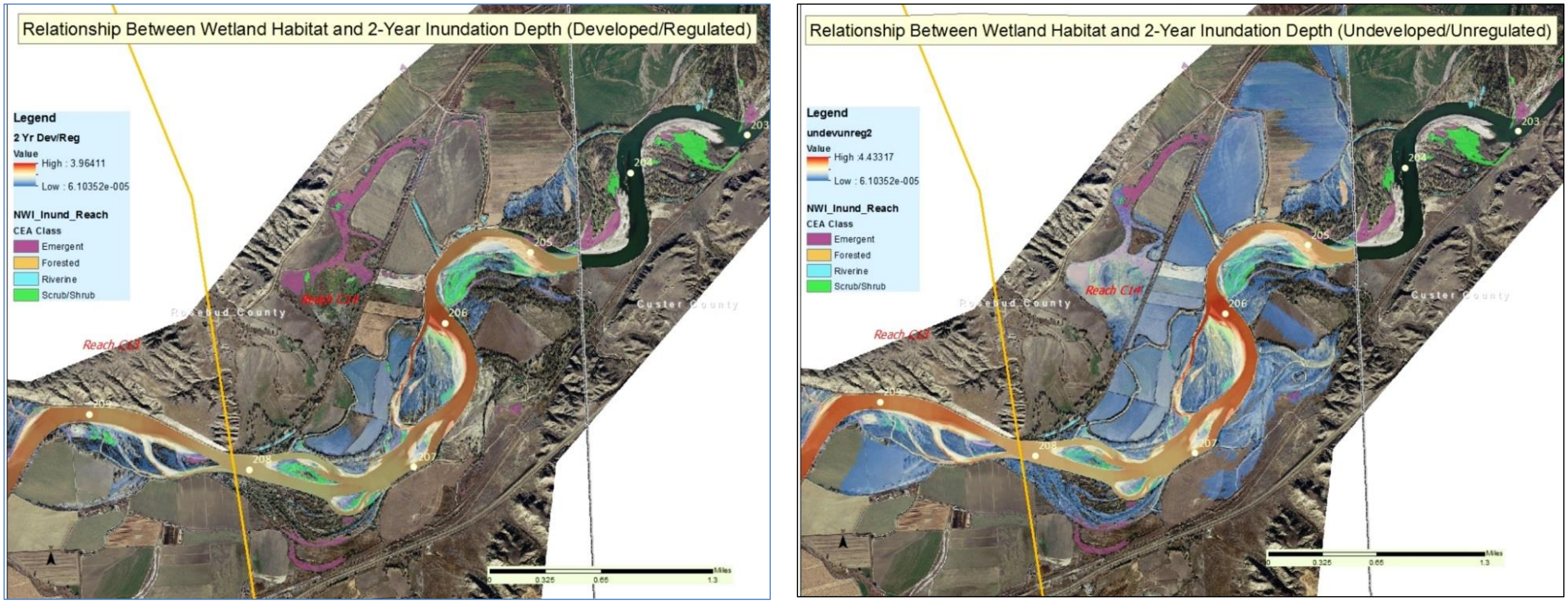


Figure 4-139 Regulated and unregulated 2-year inundation zone (flooded area) for Reach C14 (partially confined, meandering - islands)

Note: *Red/orange tint indicates deeper inundation. Also shown are the NWI wetland mapping classes. The images show how riverine and Palustrine wetlands are related to the overflow provided by the 2-year event and are impacted by reductions in flood depth. Note the herbaceous wetlands to the top of the photo (purple tint) now disconnected from the channel under the developed flow condition. This area appears to be a relict channel. Also apparent are the scrolls of scrub/shrub and riparian forest habitat adjacent to the channel on meander bends through which multiple shallow water channels flow in the undeveloped setting but are significantly diminished under the developed setting.*

4.8.4 Summary of Floodplain Restriction Impacts

Dikes, levees, and placement of road and railroad prisms create barriers to floodwater accessing the floodplain. While flood control was not always the primary intention of the fill, the result is often the same. Over 500 acres of wetlands have been isolated from the channel by floodplain features in Regions A-D. Importantly, forty percent of all wetland isolation occurs within three Reaches: A18, C14, and D13 with nearly 250 acres associated with the abandoned Milwaukee Road and the Northern Pacific railroad prism fill. The total wetland floodplain isolation represents a relatively small four percent of the total wetlands mapped within the 100-year inundation zone. Typically, an unquantified extent of wetland habitat is also directly converted by the placement of the fill footprint.

Figure 4-140 depicts the extent of isolated palustrine emergent wetland categories by cause and reach. The majority (75 percent) of the isolated wetland acres are emergent wetlands, followed by riverine wetlands (24 percent). Scrub/shrub and forested wetlands incur negligible isolation by floodplain features. Over 40 percent of the wetland isolation occurs within three reaches: A18, C14, and D13, primarily affecting emergent wetlands.

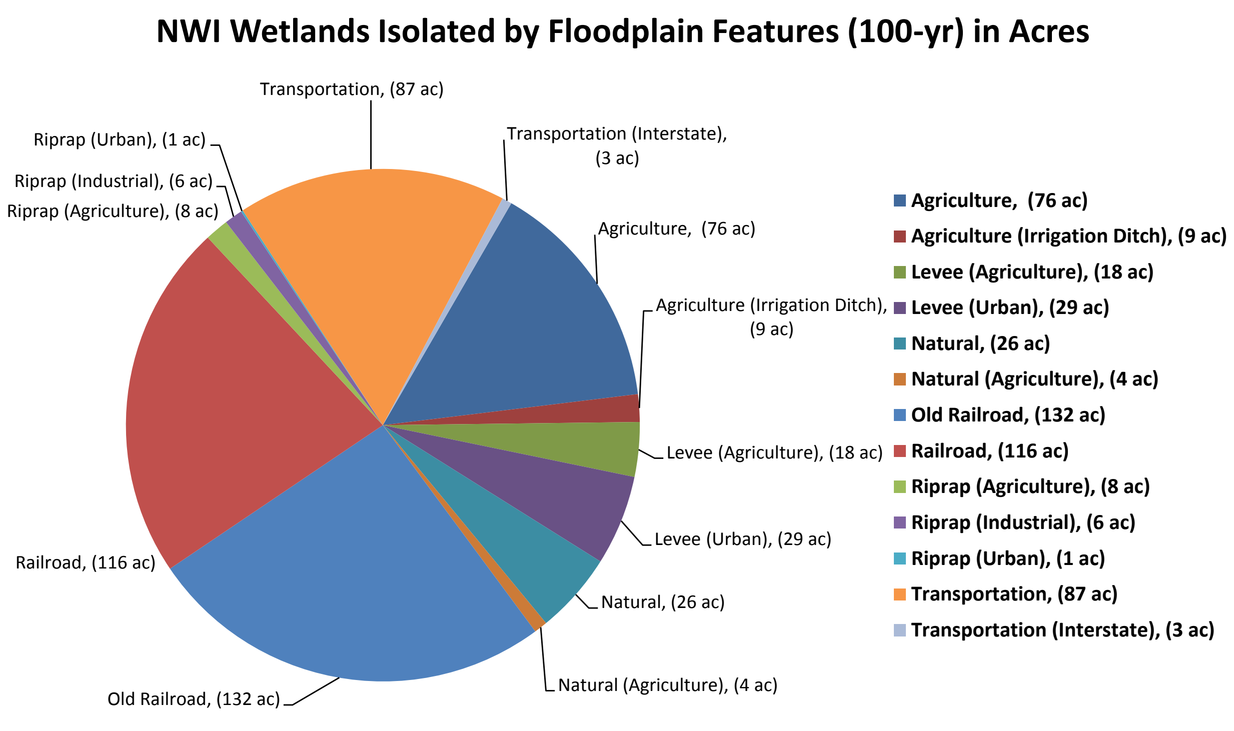


Figure 4-140 Relative extent of NWI wetlands isolated by floodplain modifying features
Note: Nearly 50 percent of the total wetland isolation is caused by railroad related fills

Even though wetland isolation may not result in total destruction of a wetland, it has been noted that when the interchange of water, sediment, nutrients, and organic matter between the channel and adjacent wetland is restricted, wetland extent and function are affected over time through the resulting alterations to the hydric moisture regime and vegetative composition (National Academy of Sciences 2002; Hauer et al. 2001). Another result of isolation is that floodplain wetlands are no longer are able to store floodwater resulting in higher flood volume and elevation (flood stage) downstream as well as loss of flow supplementation later in the year from water stored in the floodplain. Additionally, some of the riverine wetlands affected by isolation are shallow water habitats and may be locally important to aquatic species.

Floodplain features may also create palustrine wetlands in some cases by capturing or impeding flow from tributaries and upland runoff, however, as noted in 4.8.2, the value and function of these artificial wetlands is generally lower than wetlands derived from channel migration and natural river processes.

4.8.5 Summary of Channel Migration Restriction Impacts

Bank stabilization features and related physical impediments to channel movement also impact wetlands through alteration of the floodplain turnover rate. Without periodic channel movement, wetlands eventually fill in with sediment and vegetation (Kudray and Schemm 2006). The loss of seasonal side channel habitat below the Bighorn River (Section 4.4 Floodplain Connectivity: Hydraulic Analysis) also demonstrates that riverine wetlands are lost when flood flows and channel migration are diminished, as has happened since completion of the Yellowtail Dam (Godaire 2009). While some attributes of wetland hydrology and vegetation may remain, isolated wetland features lose much of their diversity and complexity in structure and composition they once had thereby losing value for wildlife and floodplain function. Loss of wetland/channel turnover also results in more simplified wetland types and function (Hauer et al. 2001).

Figure 4-141 shows that about 550 acres of wetlands in Regions A-D are located within a Restricted Migration Area (RMA) mapped as part of the Channel Migration Zone (CMZ) mapping (DTM and AGI 2009). Of the 550 wetland acres affected by channel migration restrictions**,** the majority are palustrine emergent wetlands. However, the relatively less affected riverine wetlands (190 acres) may have been locally important as fisheries habitat since this class represents seasonal, shallow water habitat in side channels. Riverine wetlands are impacted to the greatest extent in Reaches B1, B2, B3, and D13, representing 60 percent of all riverine wetlands falling within the Restricted Migration Area (RMA).

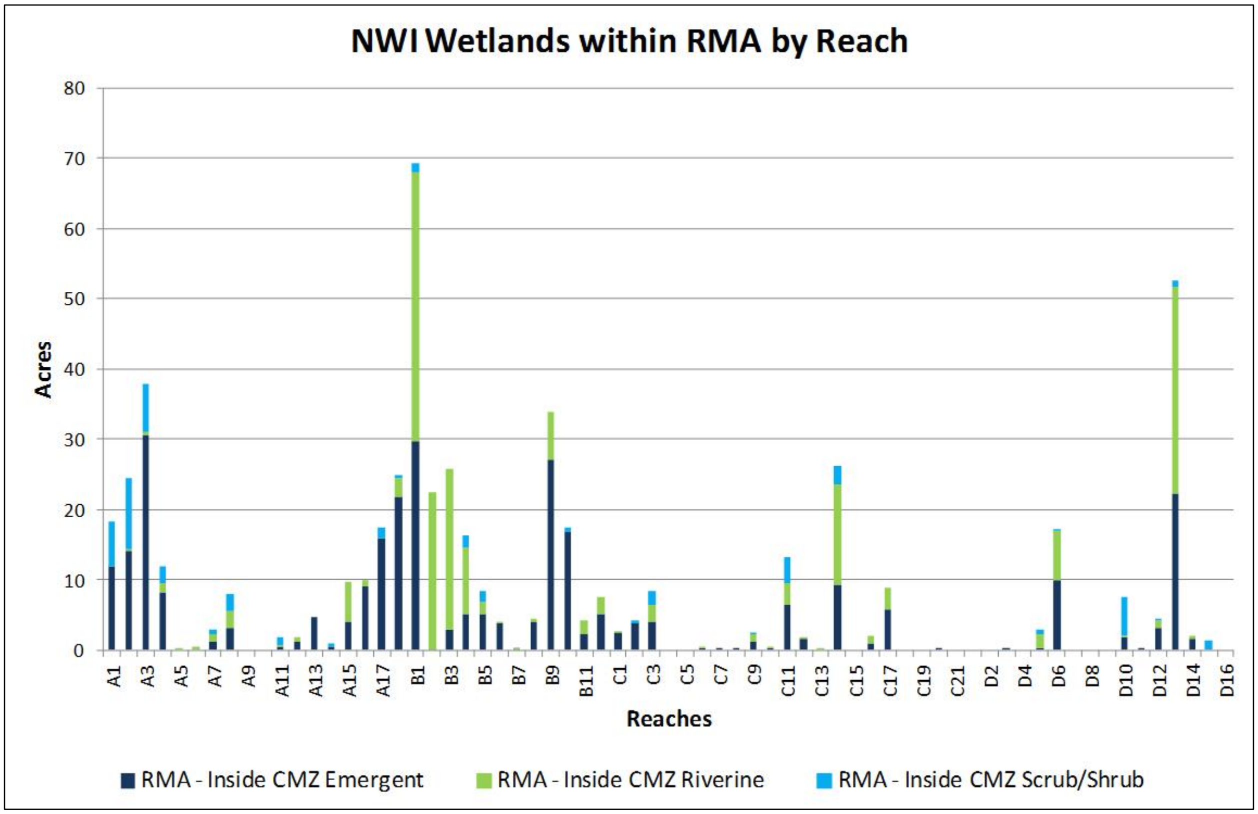


Figure 4-141 Extent of NWI wetland classifications isolated by floodplain features in affected reaches

Reach B1 was identified in Riparian Section 4.7.7 for having a large portion of riparian habitat within a RMA. Approximately 1,100 acres of riparian habitat in B1 of which 475 acres are woody riparian cover types are within a RMA, the greatest amount of any Region A-D reach. The primary cause of channel restriction in B1 is due to bank stabilization riprap and flood protection dikes and levees, so it is likely these features are also the cause of the impacts to riverine wetlands in Reach B1. In comparison, Park County has over 475 acres of NWI wetlands within an RMA (see Figure 4-142). This extent nearly equals the amount of restricted wetlands for all of Regions A through D indicating that the impact of channel restriction is much greater in this upper portion of the river, primarily due to riprap on armored banks, floodplain dikes, and levees (Hauer et al. 2001).

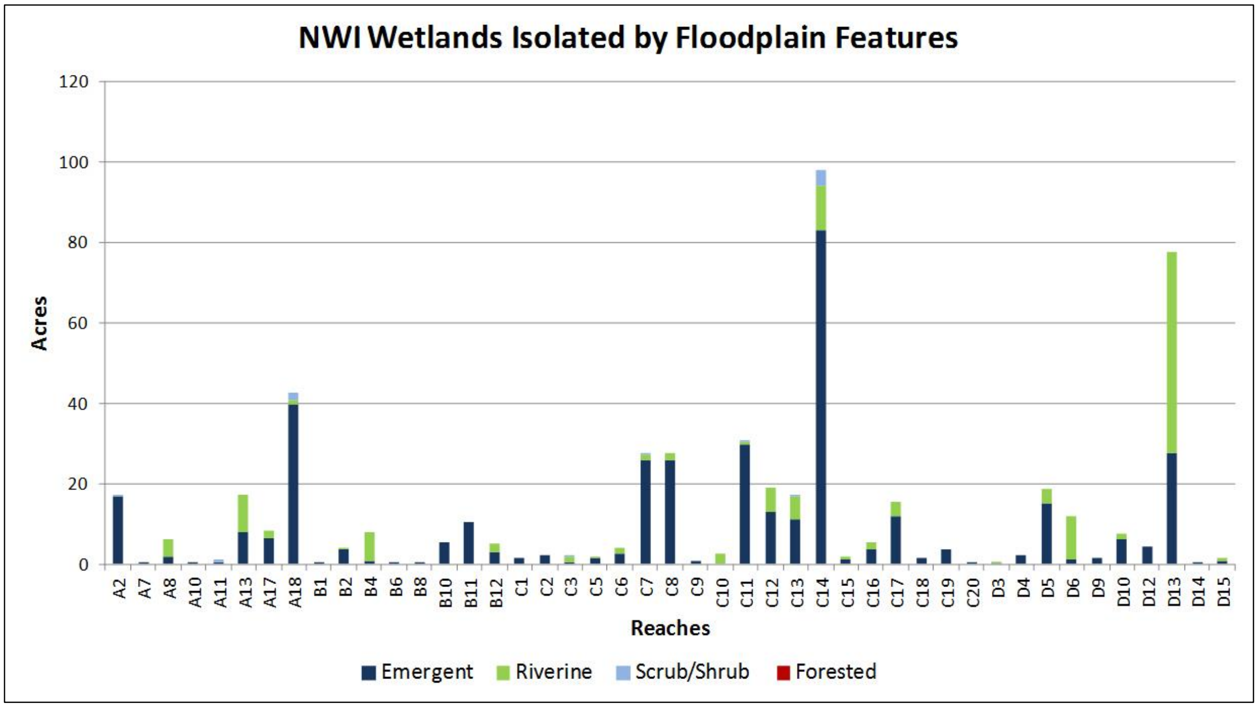


Figure 4-142 Wetlands within the Restricted Migration Area caused by the restriction of channel migration by a physical feature on the channel bank, in particular bank stabilization features

Figure 4-143 shows the relationship of wetland density to channel classification. Channels with less confinement are more dynamic. This figure shows that wetlands occur at an increasing density in reaches that are less confined. Confined and straight reaches have less wetland per river mile which is very similar to the pattern exhibited by riparian habitat (Section 4.7). Both wetland and riparian relationships validate findings that channel migration (floodplain turnover) driven by channel forming and flood flows is essential to creating and maintaining riparian and wetland habitat along the Yellowstone River.

4.8.6 Summary of Agricultural Impacts – Irrigation

No specific studies were undertaken as part of the CEA or available in the scientific literature to help quantify or qualify the impact of irrigation withdrawals or return flows in the Yellowstone corridor on wetland extent or hydrology. Irrigation can alter the hydrology of wetlands by altering the amount of water received by a wetland (Jones 2001; National Academy of Sciences 2002). In addition to irrigation ditches and canals interrupting the flow or volume of water delivered to a wetland, return flows via drains, ditches, and overland flow may also alter the seasonal hydrology of wetlands thereby changing their characteristics and functions from their natural state. Likely, some seasonal wetlands are made wetter or more persistent while the creation of irrigation system infrastructure and fields has had a negative impact by altering and converting wetlands to irrigated fields and other non-wetland uses.

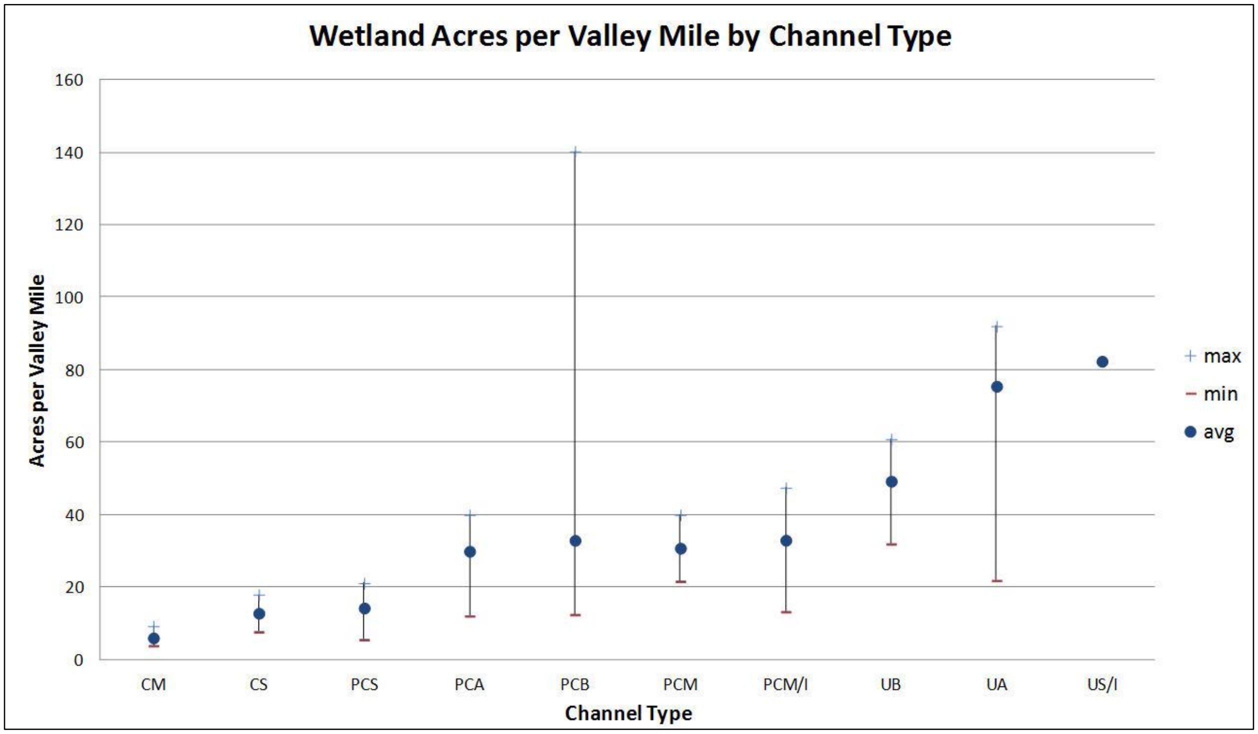


Figure 4-143 Wetland acres per valley mile by channel type (See Table 3-2 for explanation of channel type)

Note: *Wetlands exhibit increasing density as the influence of channel confinement decreases*

Returning to the discussion of hydrologic impacts in Section 4.8.3, it is apparent that the reduced summer, low flow discharge that has been linked to water withdrawals below the Clarks Fork confluence are at least in part due to irrigation with over 90 percent of water use in the Clarks Fork basin attributed to irrigation use . Impacts of reduced low water flows are similar to those described in 4.8.3 above. Lower flows deplete the local water table which in turn exposes riverine aquatic wetland sites and places stress on palustrine emergent wetland flora thereby reducing vigor and rendering wetlands more susceptible to invasion by a multitude of more drought tolerant, invasive species (see Section 4.8.8).

Citations by various authors also provide information showing that irrigation return flows that affect wetlands in many cases also bring increased sediment along with agricultural nutrients and chemicals that may be harmful to wetland ecology and the organisms living there. Some studies have shown increased rates of erosion (Dillaha et al. 1989) and pesticide losses up to one to 10 percent of that applied in irrigation return flows (Baker 1983). While sediment, nutrient, and chemical attenuation are recognized functions of wetlands, the accelerated delivery rates can overwhelm the natural wetland attenuation processes and lead to a decline in the quality of these environmental services provided by wetlands.

The Yellowstone River corridor has few of the underground, tile drainage systems utilized in the Midwestern United States to drain wetlands and manage soil moisture in irrigated lands (Pick personal observation). Most field drains in Montana are surface systems that intercept and convey surface and ground water to lower topographic areas via open ditches. More investigation by future researchers is recommended to fully understand the various impacts of irrigation systems on wetlands in the Yellowstone corridor (see the Section 4.6 for more discussion on the impacts of drainage ditches on water quality and wetland/riparian habitat).

4.8.7 Summary of Agricultural Impacts – Livestock Management

Livestock and large ungulate grazing have long been part of the history of the Yellowstone River Valley. Prior to settlement, large herds of deer (*Odocoileus spp.*), elk (Cervus Canadensis), and bison (*Bison bison*) were documented by early travelers throughout the bottomlands and uplands of the region (Confluence Consulting 2003; Brownell 2006). An early explorer of southeast Montana in 1853, Osborne Russell wrote that “The bottoms are heavily timbered with sweet cottonwood and our horses and mules are very fond of the bark which we strip from the limbs and give them every night as the buffaloe [*sic*] have entirely destroyed the grass throughout this part of the country” (Haines 1965). It should be noted that the early records do not specify for how long the bison stayed in one area. Unimpeded by fences, bison and other large ungulates were noted to follow the availability of green grass following fires so they might not return for long periods of time to any one location. Grazing preferences of bison have been noted to differ from that of cattle and their use of riparian and wetlands may have been different from that observed for livestock (Plumb and Dodd 1993; Ranglack 2014).

Current wetland impacts related to domestic livestock grazing concern season-long grazing and winter feeding operations (National Academy of Sciences 2002; Earhart and Hansen 1998). Typical issues are degradation of riparian and wetland habitat that alters plant composition, nutrient enrichment, increases in non-native species like smooth brome (*Bromus inermis*), reed canary grass (*Phalaris arundinacea*), meadow foxtail (*Alopecurus pratensis*), and Kentucky bluegrass (*Poa pratensis*), and decreased soil cover (Jones 2001; Eggers 2005; Kudray 2005) along with ‘pugging’ (Knight et al. 2014). This latter feature is visible as the mounds and divots created by intensive hoof action on wetland soils which fosters sedimentation and encourages invasive species. Many invasive species like Russian olive (*Elaeagnus angustifolia*), saltcedar (*Tamarix* spp.), (Canada thistle (*Cirsium arvense*), leafy spurge (*Euphorbia esula*), and spotted knapweed (*Centaurea maculosa*) are favored since they are not readily consumed by livestock or wildlife.

No comprehensive or systematic inventories of wetland condition or health status have been conducted in the Yellowstone River corridor. As a result, little information is available to support a detailed assessment of wetland condition or functional status as part of the Cumulative Effects Analysis (CEA). The relatively small sample sizes of the Yellowstone specific studies (Jones 2001; Eggers 2005; Hauer et al. 2001) does not allow direct application of this information to all NWI wetlands within the Yellowstone corridor, however, these studies in conjunction with those in the literature review provide some indications that at least a portion of the wetlands in the corridor are functionally impaired due in part to livestock grazing and other human caused stresses and are in need of restoration. The extent, degree, and distribution of wetlands in need of restoration are unknown. Further study is recommended to help guide future wetland restoration recommendations and integration with other study components.

4.8.8 Summary of Invasive Species Impacts

Invasive species frequently replace native species in wetlands due to their competitive advantage resulting in a simpler, more homogenous plant community that supports less diverse wildlife populations. Russian olive and saltcedar have been recognized as noxious weeds in Montana in riparian and wetland environments (Pick 2013; Lesica and Miles 2001). Russian olive seed lasts decades and the plant flourishes in slightly wet, saline sites where livestock and wildlife do not browse on the thorny vegetation. Russian olive also is tolerant of shade as well as growing in direct sunlight. Russian olive also may alter the habitat such that other exotics organisms are attracted and flourish, which degrades the environment for native wildlife species either through increased competition or parasitism (Lesica and Miles 2001).

Saltcedar favors bare, moist, slightly saline soil where it quickly develops an extensive root system. Once mature, the plant produces seed continuously during the growing season. The combination of shed leaves containing high levels of salt and dense vegetative growth often results in a very dense, pure stand of saltcedar with bare ground beneath (Pick 2013; Jacobs and Sing 2007).

The NRCS Russian olive mapping (Coombs and Potter 2011) project used automated image analysis methods to identify Russian olive captured in the 2008 NAIP multi-spectral imagery. This inventory was used to evaluate the impact of Russian olive on National Wetlands Inventory (NWI) wetlands (USFWS 2014) within the 100-year inundation boundary. Figure 4-144 depicts the extent of Russian olive occurring within NWI wetland classes. Russian olive infestation primarily impacts the shrub/scrub and emergent wetland types. On average, a relatively small area, 180 acres or one percent of all NWI wetlands within the 100-year inundation boundary, are impacted, although some reaches are impacted to a greater degree (Figure 4-145).

While relatively low at the present time, Russian olive densities can increase rapidly into suitable habitats. Reaches C10 to C20, excepting C14, have the greatest presence of Russian olive in wetlands. The implications are that while a majority of NWI wetlands (as of 2008) are being affected, due to the delayed spread mechanism of Russian olive, once a threshold population of sexually mature plants is reached (at 5 to 7 years of age), spread occurs at a much higher rate. The threat is likely to be increasing. Importantly, the emergent and shrub/scrub wetlands are those where Russian olive could provide serious competition for establishing young native species such as sandbar willow, plains cottonwood and herbaceous, native wetland species.

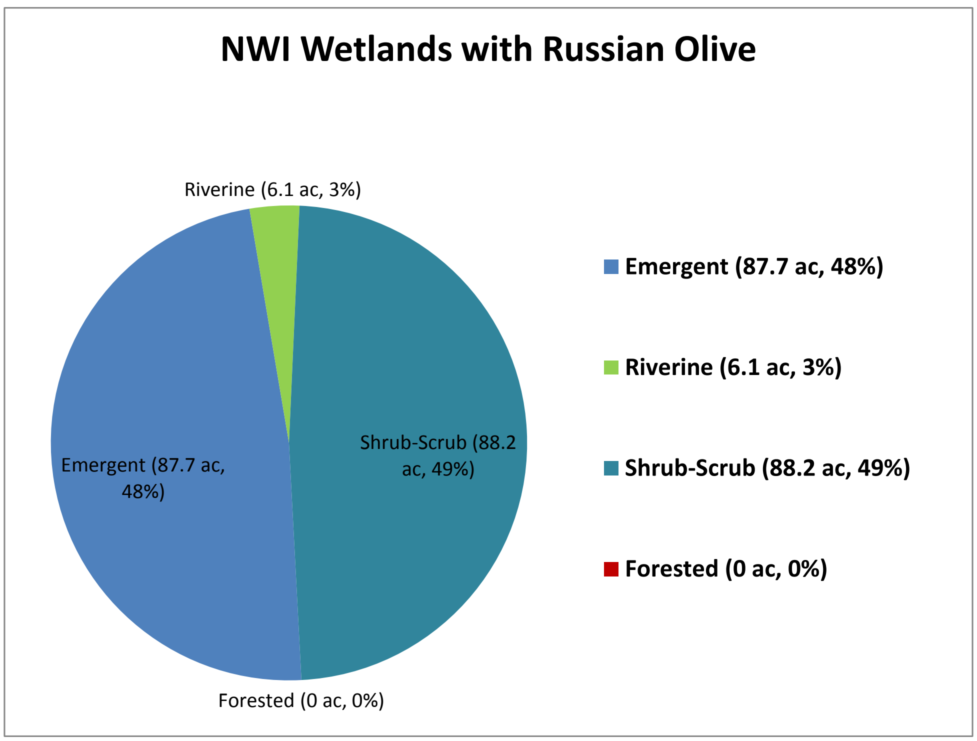


Figure 4-144 Relative extent of NWI wetland types within the 100-year inundation boundary with Russian olive presence

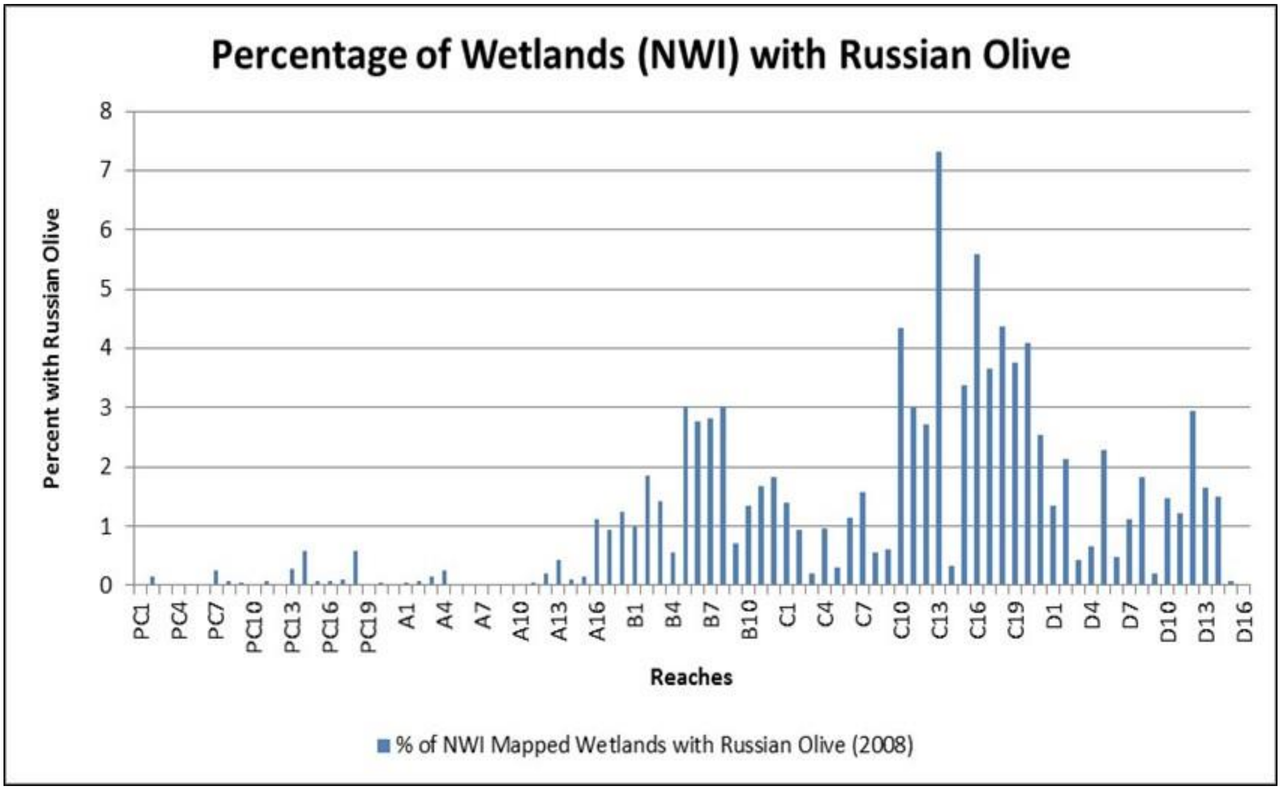


Figure 4-145 Percentage of wetlands (NWI) with Russian Olive
Note: *Wetlands in the middle and lower Yellowstone River (within the 100-year inundation boundary) have higher presence of Russian olive than do upper Reaches*

Control priorities should focus on reaches in the upper watershed (Regions A and B) with very little Russian olive or saltcedar to keep the pristine areas free and secondarily on those areas with light infestations. The upper watershed provides a seed source for downstream areas so control is futile in the lower watershed without control in the upper regions. Dense or higher infestations require significantly more effort and cost to restore native riparian and wetland species. Also, the focus of control efforts should be on maintaining higher value scrub/shrub and emergent wetlands.

Since there is no comprehensive database of saltcedar occurrence in the river corridor to depict density and distribution at this time, more collaboration is needed to define present and future saltcedar control opportunities and to provide a baseline for evaluating control activities. Due to its adaptation to colonize fresh sand and gravel bars (Graf 1978), riverine and palustrine unconsolidated shore wetlands are likely most at risk of infestation by saltcedar.

Because palustrine and riverine wetlands are created and destroyed through the processes of erosion and sedimentation (Merigliano and Polzin 2003), these fluvial processes also render the freshly disturbed sites very susceptible to invasion by many other exotic species. Initially barren gravel bars and sediment deposits are fertile ground for invasive species, as well as native plants. Jones (2001) noted that hounds tongue (*Cynoglossum arvense*), Canada thistle, leafy spurge, and spotted knapweed are serious pests that threaten many wetlands along the Yellowstone River. Impaired wetland functions and values result if invasive weeds are allowed to spread uncontrolled (Eggers 2005; Graf 1978).

A number of wetland specific invasive species (Table 4-18) have been found in counties in or near the Yellowstone watershed. Typically, these species are somewhat more drought tolerant or aggressively reproductive than the indigenous native species they replace. Vigilance and landowner education is recommended to prevent infestation or expansion of these species in the Yellowstone River watershed (see http://mtweed.org for more information on identification and control of noxious weeds in Montana).

Table 4-18
Aquatic Invasive Species in Montana with Potential to Invade the Yellowstone River System

Common name	Genus/species	Status	Flower	Growth habit	Comments
Yellow flag iris	*Iris pseudacorus*	Perennial noxious weed	Yellow	Full sun	Poisonous and skin irritant
Purple loosestrife	*Lythrum spp.*	Perennial noxious weed	Purple to magenta	Full sun	Spreads by seeds and roots
Perennial pepperweed	*Lepidium latifolium*	Perennial noxious weed	Small, white	Sun or shade, wet and dry	Toxic to livestock and alleopathic to woody plants
Eurasian water milfoil	*Myriophyllum spicatum*	Aquatic perennial noxious weed	inconspicuous	Submersed	Aggressively reproduces vegetatively and by seed (less so)
Curly leaf pondweed	*Potamageton crispus*	Aquatic perennial noxious weed	inconspicuous	Floats just below surface	Winter buds called 'turions' on stem
Flowering rush	*Butomus umbellatus*	Aquatic perennial noxious weed	Pink and white	Emergent or submerged	Reproduces by seed and roots (bulblets)

4.8.9 Other Potential Impacts on Wetland Systems

As described in the preceding sections of this chapter, there are a number of potential human influences on wetlands within the Yellowstone River corridor. Based on the available studies and related literature, those described previously are thought to be the most significant sources of wetland alteration or change. Given the scarcity of Yellowstone specific studies with quantitative and qualitative data, there could be other possible impacts that have or will affect wetlands within the Yellowstone River corridor. These potential impacts are described in the following sections.

4.8.9.1 Climate Change or More Variability in Extremes

As a result of constraints in time and financial resources, specific climate projections and analyses have not been made under the auspices of the Yellowstone Cumulative Effects Analysis (CEA), but are encouraged to be undertaken as resources are available by those who follow this work. Following are a few impacts suggested by a review of climate change literature relative to the Yellowstone ecosystem.

Climate change has the potential to impact wetlands in the Yellowstone River corridor in several ways in the short- and long-term. Given their reliance on water, wetlands are vulnerable to changes in water availability, duration, or timing that are driven by variability in climate. Based on studies of past climate, less precipitation and warmer winter temperatures may have been more the norm in the Yellowstone River Basin (Graumlich, et al 2003). More recently, in the northern Great Plains area, which encompasses the Yellowstone River Basin, precipitation decreased by 10 to 20 percent between 1990 (IPCC 1998). In the short-term, this is a potential slight impact. However, longer-term impacts may be considered moderate as temperatures warm more and impacts accumulate over time. Warmer air and water temperatures coupled with reduced and earlier snowmelt can be expected to negatively affect wetland

and riparian ecosystems in the Yellowstone River Basin (Chang and Hansen 2014 ; Leppi et al. 2011; Miller et. al. 2008). In addition to direct impacts, a warmer and more arid climate will increase the habitat suitability in all wetlands for a number of invasive species.

Wetland degradation may increase releases of stored carbon dioxide (CO_2) once organic matter stored in drying wetland soil begins to decompose (Burkett and Kusler, 2000 cited in US Army Corps of Engineers 2014). Isolated, extreme weather events with intense precipitation evaluated under climate change models (US Army Corps of Engineers 2011) may result in larger magnitude floods in a Yellowstone River with less wetland and riparian habitat available to store floodwater.

4.8.9.2 Municipal and Industrial Water Use

As sectors of overall water withdrawals on the Yellowstone River, municipal and industrial water users are relatively small users. Compared to agricultural withdrawals, municipal water use in counties along the river is relatively minor, making up less than one percent of the daily water use. Industrial water use is somewhat greater, but only comprises around eight percent of agriculture's use (Section 4.3 Hydrology). However, it was also noted that industrial uses consume water in the lower river which could have impacts on flow downriver during low flow periods.

Population in the entire Yellowstone basin increased about 12 percent in the 10 year period between 2002 and 2012 (Frankforter et. al. 2015, in review). With projected future increases in population and industry (mining, oil and gas development), increased water demand will occur in the future (Montana DNRC 2014). This additional demand can heighten the impact of total water withdrawals during low flow periods, particularly when coupled with possible climate change or variability as discussed above. Minimum flow water rights held by the Montana Fish, Wildlife & Parks can help to alleviate impacts but these rights are not senior to other, older water rights. Data or metrics for this analysis and potential impacts on wetlands have not been made but would be expected to parallel the subjective reasoning in the preceding sections.

4.8.9.3 Urban/Exurban Development

The majority of past conversion and alteration of wetland habitats has been related to agriculture, primarily because of the dominant spatial extent of agricultural land uses corridor. While agricultural land uses will likely not expand greatly in the future, it is expected that urban and exurban land uses will continue to grow as population expands within the corridor. Current laws and regulations (Clean Water Act, Montana Stream Protection Act of 1963, the 1975 Natural Streambed and Land Preservation Act, and the 1973 Montana Floodplain and Floodway Management Act) serve to protect most Palustrine and Riverine wetland environments to some degree. Continued growth will bring pressure to convert some areas for housing and infrastructure so future impacts of urban/exurban development could be significant near urban centers like Billings, Miles City, and Glendive unless additional programs are instituted to provide viable economic alternatives to development within the corridor. Mechanisms and policies are recommended to encourage further use of channel migration easements offered by MFWP and other non-profit easement programs to help provide alternatives to development in the floodplain.

4.8.9.4 Changes in Water Quality

The documented reductions in low flow discharge (Section 4.3 Hydrology) on the Yellowstone below the Clarks Fork River confluence, coupled with other potential increases in water demand, could further reduce low flows, especially in the lower river below the Bighorn River confluence. Further reductions in flow have the potential to increase concentrations of water quality contaminants as described in Section 4.6 Water Quality to a point that beneficial uses could be threatened. Increases in salinity, dissolved solids, water temperature, nutrients, and other water quality metrics could adversely impact riverine wetlands as well as closely connected palustrine wetlands. Changes in reduced native species recruitment, species composition, and increased susceptibility to invasion by exotic species tolerant of elevated levels of salt and nutrients are expected impacts of water quality changes on wetlands.

4.8.9.5 Transportation Impacts

Transportation related impacts currently affect a relatively low extent of wetlands, primarily by isolating them from the floodplain as described in Section 4.8.4. Approximately 340 acres are impacted by the action of transportation fills blocking flood flows to wetlands behind the fills. Many of these fills also restrict channel movement which magnifies the long-term impact. The great majority of transportation isolation impact on palustrine and riverine wetlands (78 percent) is due to construction of the two railroads on both banks of the river. The potential for substantial future additional impact of transportation on wetlands is considered to be minimal due to current regulations and laws that require consideration of alternatives and mitigation for unavoidable alteration of regulated wetlands (Tillinger 2010).

The relatively significant funding provided for transportation infrastructure facilitates wetland mitigation of future and past transportation impacts to wetlands when appropriate. A number of riparian and wetland mitigation banks have been instituted in Montana to enable mitigation trading. Potential for mitigation on the now abandoned Milwaukee Road rail bed prism is greater as ownership has been fragmented and in many cases reverted to the local land owner who may be more willing to address the impacts of the fill. Efforts to identify and prioritize potential mitigation projects involving transportation-related impacts to wetlands should be encouraged.

4.9 Biology: Aquatic Animals (Fisheries)

4.9.1 Introduction

This section describes the extent and nature of primary human influences affecting the fish community of the Yellowstone River. It provides a synopsis of technical information provided in Appendix 8 (Fisheries), which contains an expanded summary of this analysis performed in support of the CEA. The Yellowstone River remains the longest unimpounded river in the contiguous United States. However, several human-caused factors influence the river’s fish community. Humans directly influence many physical aspects of the Yellowstone River ecosystem through changes in hydrology and land use for example, however these changes have secondary influences on the fish community.

4.9.2 The Yellowstone River Fish Community

The Yellowstone River fish community has about 59 fish species total of which 22 species (37 percent) are nonnative (Table 4-19; White and Bramblett 1993). However, in terms of abundance, most nonnative fish are rare, with the exception of Rainbow Trout and Brown Trout in the uppermost about 250 miles of river. The Yellowstone River has 14 fish and two reptile species of concern, including the endangered Pallid Sturgeon (Table 4-20; Montana Natural Heritage Program 2015). However, the primary habitat for five species is tributaries of the Yellowstone River, rather than the Yellowstone River mainstem (Table 4-20).

Table 4-19
Fishes of the Yellowstone River

Family	Common name	Scientific name
Acipenseridae	Pallid Sturgeon	*Scaphirhynchus albus*
	Shovelnose Sturgeon	*Scaphirhynchus platorynchus*
Polyodontidae	Paddlefish	*Polyodon spathula*
Lepisosteidae	Shortnose Gar	*Lepisosteus platostomus*
Hiodontidae	Goldeye	*Hiodon alosoides*
Cyprinidae	Northern Redbelly Dace[b]	*Chrosomus eos*
	Lake Chub[b]	*Couesius plumbeus*
	Common Carp[a]	*Cyprinus carpio*
	Western Silvery Minnow	*Hybognathus argyritis*
	Brassy Minnow[b]	*Hybognathus hankinsoni*
	Plains Minnow[b]	*Hybognathus placitus*
	Sturgeon Chub	*Macrhybopsis gelida*
	Sicklefin Chub	*Macrhybopsis meeki*
	Emerald Shiner	*Notropis atherinoides*
	Sand Shiner	*Notropis stramineus*
	Spottail Shiner[a]	*Notropis hudsonius*
	Fathead Minnow	*Pimephales promelas*
	Golden Shiner[a]	*Notemigonus crysoleucas*
	Flathead Chub	*Platygobio gracilis*
	Longnose Dace	*Rhinichthys cataractae*
	Redside Shiner[a]	*Richardsonius balteatus*
	Creek Chub[b]	*Semotilus atromaculatus*
Catostomidae	River Carpsucker	*Carpiodes carpio* (see Figure 4-146)
	Blue Sucker	*Cycleptus elongatus*
	Longnose Sucker	*Catostomus*
	White Sucker	*Catostomus commersonii*
	Mountain Sucker	*Catostomus platyrhynchus*
	Smallmouth Buffalo	*Ictiobus bubalus*
	Bigmouth Buffalo	*Ictiobus cyprinellus*
	Shorthead Redhorse	*Moxostoma macrolepidotum*
Ictaluridae	Black Bullhead[a, b]	*Ameiurus melas*
	Yellow Bullhead[a, b]	*Ameiurus natalis*
	Channel Catfish	*Ictalurus punctatus*
	Stonecat	*Noturus flavus*
Esocidae	Northern Pike[a]	*Esox lucius*
Osmeridae	Rainbow Smelt[a]	*Osmerus mordax*
Salmonidae	Yellowstone Cutthroat Trout	*Oncorhynchus clarkii bouvieri*
	Rainbow Trout[a]	*Oncorhynchus mykiss*
	Mountain Whitefish	*Prosopium williamsoni*
	Brown Trout[a]	*Salmo trutta*

Family	Common name	Scientific name
	Brook Trout[a]	*Salvelinus fontinalis*
	Lake Trout[a]	*Salvelinus namaycush*
Lotidae	Burbot	*Lota lota*
Fundulidae	Northern Plains Killifish[a, b]	*Fundulus kansae*
Cottidae	Mottled Sculpin	*Cottus bairdii*
Gasterosteidae	Brook Stickleback[b]	*Culaea inconstans*
Moronidae	White Bass[a]	*Morone chrysops*
Centrarchidae	Rock Bass[a]	*Ambloplites rupestris*
	Green Sunfish[a]	*Lepomis cyanellus*
	Pumpkinseed[a]	*Lepomis gibbosus*
	Bluegill[a]	*Lepomis macrochirus*
	Smallmouth Bass[a]	*Micropterus dolomieu*
	Largemouth Bass[a]	*Micropterus salmoides*
	White Crappie[a]	*Pomoxis annularis*
	Black Crappie[a]	*Pomoxis nigromaculatus*
Percidae	Yellow Perch[a]	*Perca flavescens*
	Sauger	*Sander canadensis*
	Walleye[a]	*Sander vitreus*
Sciaenidae	Freshwater Drum	*Aplodinotus grunniens*

[a] *Not native to the Yellowstone River.*
[b] *Primary habitat for this species is tributaries of the Yellowstone River, rather than the Yellowstone River main stem.*

Figure 4-146 River Carpsucker

Table 4-20
Fish and Reptile Species of Concern of the Yellowstone River

Common name	State rank[a]	Federal status	Approximate longitudinal distribution
Pallid Sturgeon	S1	Endangered	Mouth to Powder River
Paddlefish	S2		Mouth to Powder River
Shortnose Gar	S1		Mouth to Sidney
Northern Redbelly Dace	S3		Mouth to O'Fallon Creek[b]
Brassy Minnow	S4		Mouth to Pryor Creek[b]
Plains Minnow	S4		Mouth to Clarks Fork[b]
Sturgeon Chub	S2S3		Mouth to Tongue River
Sicklefin Chub	S1		Mouth to Intake
Creek Chub	S4		Mouth to Rosebud Creek[b]
Blue Sucker	S2S3		Mouth to Bighorn River
Yellowstone Cutthroat Trout	S2		Billings to headwaters
Burbot	S4		Mouth to Boulder River
Brook Stickleback	S4		Mouth to Clarks Fork[b]
Sauger	S2		Mouth to Clarks Fork
Spiny Softshell	S3		Mouth to Clarks Fork
Snapping turtle	S3		Mouth to Bighorn River

a. *S1, At high risk because of extremely limited and/or rapidly declining population numbers, range and/or habitat, making it highly vulnerable to global extinction or extirpation in the state; S2, At risk because of very limited and/or potentially declining population numbers, range and/or habitat, making it vulnerable to global extinction or extirpation in the state; S3 Potentially at risk because of limited and/or declining numbers, range and/or habitat, even though it may be abundant in some areas; S4, Apparently secure, though it may be quite rare in parts of its range, and/or suspected to be declining (Montana Natural Heritage Program 2014).*
b. *Primary habitat for this species is tributaries of the Yellowstone River, rather than the Yellowstone River main stem.*

The fish community changes along the river from its coldwater, alpine headwaters above Yellowstone Lake in Wyoming to its warmwater, prairie confluence with the Missouri River in North Dakota. Riverine ecosystems follow a longitudinal continuum in which physical and biological conditions are connected and shift gradually (Vannote et al. 1980). However, the Yellowstone River fish community can be generally described as having three fish zones: an upper coldwater zone from the headwaters to the mouth of the Clarks Fork, a transition zone from the Clarks Fork to the mouth of the Bighorn River, and a warmwater zone from the Bighorn to the confluence with the Missouri River (White and Bramblett 1993). The number of fish species found in the river increases going downstream. The coldwater zone has about 16 fish species; primarily salmonids (trout and Mountain Whitefish), sculpins, and some minnows and suckers. The transition zone has about 30 fish species; including more minnow and sucker species, four catfish species, Burbot, Sauger, Walleye, and Smallmouth Bass. The warmwater zone has about 49 total species, and adds two sturgeon species, the Shovelnose Sturgeon and the endangered Pallid Sturgeon (see Figure 4-147), Paddlefish, more minnow species, including Sturgeon Chub and Sicklefin Chub, the Blue Sucker, and about six introduced sunfishes. The lower Yellowstone River has the highest fish species richness in Montana, and therefore is a stronghold of native fish diversity.

Figure 4-147 Shovelnose Sturgeon

4.9.3 Major Findings in Support of Cumulative Effects Analysis

The primary direct human influences on the Yellowstone River are altered hydrology and hydraulics, geomorphology, riparian vegetation, wetlands and riparian vegetation, land use, longitudinal connectivity, main river to tributary connectivity, water quality, and introduced species. These human influences in turn secondarily influence the fisheries of the Yellowstone River. Humans also directly influence Yellowstone River fish though recreational fishing.

Major findings of this assessment include the following:

- Altered hydrology has a number of potential effects on the fish community including:
    - Increased floodplain isolation which is important for the river's food web and as habitat for fish.
    - Reduced side channel availability; side channels are important fish, amphibian, and reptile habitats.
    - Disrupting cues for fish movements and reproduction.
    - Diminished channel migration rates which reduces Large Woody Debris (LWD) recruitment, reduces creation and maintenance of diverse habitats, and reduces natural sediment supply.
    - Reducing summer low flows which may increase temperature, and the rates of predation, competition and disease transmission.
    - Increased temperatures may influence the distribution of fish.

    - Increased fall and winter discharges may increase fish energy needs during the cold low-metabolism season, alter ice dynamics and jamming, and reduce the influence of the low-elevation snowmelt pulse as a fish movement or spawning cue.

    - Reduced hydrograph rise and fall rates may disrupt or weaken hydrologic spawning cues.

    - Reduced discharge from the Bighorn River and other tributaries has altered the ecological suitability of native fish habitat the tributary as well as in the mainstem Yellowstone River.

- Altered geomorphology has a number of potential effects on the fish community including increased floodplain isolation and side channel availability as described above.

- Bank stabilization affects fish communities by increasing floodplain isolation, altering main channel habitats, and reducing the availability of diverse lateral habitats such as side channels and backwaters.

- Altered riparian vegetation and wetlands affects many natural functions of the river that are important to fish such as dissipating flood energy, trapping sediments, filtering nutrients and other pollutants, providing fish and wildlife habitat, and contributing to the biological productivity of the aquatic ecosystem.

- Altered land use and conversion of floodplain areas to other uses such as irrigated agriculture, urban and exurban areas may increase pollution, alter urban stream hydrology, and reduced recruitment of LWD, which in turn may affect the fish community.

- Altered longitudinal connectivity on the Yellowstone River is caused by six mainstem diversion dams. Although the degree of fragmentation of fish populations caused by these dams is not fully understood for all dams and fish species, these dams potentially affect the distribution of some fish species and reduce the viability of some fish populations.

- Altered mainstem to tributary connectivity due to diversions, culverts, and other barriers affects the fish community because many fish species use both habitats at some point in their life histories.

- Altered water quality on the Yellowstone River is generally moderate and the potential effects on the fish community are unknown. However, catastrophic events such as oil pipeline ruptures and associated oil spills have the potential for stronger impacts on the fish community.

- Fish entrainment in water withdrawal structures occurs in the Yellowstone River. Although the Intake and Tongue & Yellowstone Irrigation District (T&Y; on the Tongue River) diversion structures are screened which has reduced loss of fish, entrainment probably remains as a considerable source of mortality for Yellowstone River fishes.

- Introduced species. In the coldwater zone of the river, introduced rainbow and brown trout dominate the fishery, and have contributed to the decline of the native Yellowstone Cutthroat Trout. Although most introduced fish species are relatively rare in the middle and lower river, the effect of introduced predators such as Smallmouth Bass, Walleye, and Northern Pike has not been studied. American Bullfrogs are established in the river floodplain near Billings and have the potential to cause declines in native amphibians and reptiles.

- Recreational fishing is an important cultural and economic activity on the Yellowstone River. Sport fish populations are monitored and managed for sustainability by Montana Fish, Wildlife & Parks.

4.9.4 Summary of Results: Anthropogenic Factors Influencing Fish in the Yellowstone River

4.9.4.1 Altered Hydrology

The hydrology of the Yellowstone River has been altered relative to unregulated (undeveloped) conditions (Appendix 2 (Hydrology); Section 4.3; Chase 2013; Chase 2014; Watson 2014). The major changes to the hydrology that were identified from the cumulative effects analysis were: reduced peak flows, earlier peak flows, decreased channel forming flows, reduced summer low flows, increased fall and winter low flows, reduced hydrograph rise and fall rates, and reduced discharge from the Bighorn River and other tributaries. The magnitude and causes of hydrological change on the Yellowstone River compared to natural flows varies from upstream to downstream. In the upper river, downstream to the Clarks Fork, hydrological change is minor and is mostly caused by irrigation. In the middle river, downstream to the Bighorn River, hydrological change is moderate and is also mostly attributable to irrigation. In the lower river, downstream to the Missouri River, hydrological change is major and is attributable to altered hydrology on the Bighorn River from Yellowtail Dam operations and irrigation. Other causes of altered hydrology include damming of other Yellowstone River tributaries, non-irrigation withdrawals of surface and ground water (Watson 2014), and climate change (Leppi et al. 2012).

Changes to the hydrology of the Yellowstone River Basin have likely had ecological consequences and influence the fish community. A river's hydrograph is often considered the “master variable” that most strongly influences riverine ecosystems (Poff et al. 1997; Bunn and Arthington 2002; Poff et al. 2010). Important mechanisms link hydrology to aquatic biodiversity. For example, streamflow is a major driver of aquatic habitat, aquatic species have evolved survival adaptations response to the natural flow regime, flow-dependent longitudinal and river to floodplain connectivity supports populations of riverine species, and the invasion of introduced species is often helped by alterations in flow regimes (Bunn and Arthington 2002).

The premise that changes in hydrology result in changes in ecology is well-established in the scientific literature. A review of 165 scientific papers indicated that 152 (92 percent) of papers reported decreases in ecological metrics for macroinvertebrates, riparian vegetation, or fish in response to a variety of flow alterations (Poff and Zimmerman 2010). This literature review corroborates the findings of an earlier review that indicated that 56 of 65 (86 percent) studies demonstrated that flow modifications were associated with ecological changes (Lloyd et al. 2003). Fish abundance, diversity, and population dynamics consistently declined in response to both reductions and increases in magnitude of discharge (Poff and Zimmerman 2010). The magnitude of change in flows in the reviewed papers was large (e.g., flows decreased by 50–100 percent or increased by 75–100 percent), and the changes in fish abundance, and particularly fish diversity, were also large (e.g., usually over 50 percent in fish abundance or diversity). No studies evaluated the change in fish communities resulting from smaller (i.e., <50 percent) changes in flows, therefore there is little available inference available for determining thresholds of hydrological change required to cause change in fish communities (Poff and Zimmerman 2010).

Larger hydrological changes were associated with increased probability that the river's ecosystem would change (Poff and Zimmerman 2010). The greatest hydrological change on the Yellowstone River has occurred below the Bighorn River (Appendix 2 (Hydrology)), therefore the greatest ecological change has probably also occurred below the Bighorn River. This is also the section of the river with the most fish species. Therefore, changes in the Yellowstone River's hydrology are of profound concern with respect to the fish community. Although ecological principles and scientific literature strongly indicate that changes in hydrology lead to changes in fish communities, the specific relationships between changes in hydrology and changes in fish communities have not been studied in the Yellowstone River.

A riverine ecosystem is connected in four dimensions (Ward 1989): longitudinal (upstream-downstream), lateral (river channel-floodplain), vertical (river channel-ground water), and temporal (time, from behavioral response time to evolutionary time). The focus of this chapter is on the longitudinal and lateral dimensions because little information is available on the Yellowstone River regarding vertical and temporal connections. The longitudinal dimension is defined by transport of nutrients, energy production, organic materials, and organisms along the river as outlined by the river continuum concept (Vannote et al. 1980). The river continuum concept emphasizes that rivers have a continuous longitudinal gradient in physical variables, and that the organisms in the river respond and adapt to this gradient. The lateral dimension is defined by the connection of the main river channel to its floodplain, and results in a continuum of habitats in floodplains ranging from terrestrial, to non-flowing, to flowing water. The flood pulse concept (Junk et al. 1989) describes the importance of the connection of the river with its floodplain that occurs during floods (particularly in large rivers), and results in exchanges of water, sediment, nutrients, energy, and organisms. Floodplains contain riparian vegetation and wetlands which provide many ecological services such as recharging ground water, and providing wildlife habitat, and floodplains are the source of large woody debris (LWD)(e.g., trees) that recruit to the river channel where they provide important fish and macroinvertebrate habitat.

Reduced Peak Flows

Peak flows have been reduced on the Yellowstone River, particularly below the Bighorn River where, for example, the magnitude of the 2-year flood has been reduced about 23 percent (Appendix 2 (Hydrology)). A reduction in peak flows reduces the stage (water surface elevation) and erosive force of the river, resulting in floodplain isolation, which decreases the area and diversity of available aquatic habitats. For example, below the Bighorn River, the Yellowstone River is now smaller, with fewer and less-frequently flowing side channels. Also, the area of open gravel and sand bars has been reduced because riparian vegetation grew on these bars, converting them to woody islands (Appendix 6 (Terrestrial Plants (Riparian Systems))).

Floodplain isolation reduces the amount of area inundated by water, particularly in habitats such as side channels, seasonal high flow channels, wetlands, and floodplain as compared to undeveloped (no dams or water withdrawals) conditions. Floodplain isolation also results from altered geomorphology from physical structures such as dikes, levees, transportation embankments, and bank armoring as well as agricultural development (Appendix 3 (Floodplain Connectivity)). For example, between Springdale and the mouth of the Yellowstone River, over 21,000 acres of 100-year floodplain have been isolated from all causes. Although no precise measure of change in Yellowstone River wetlands is feasible, an estimated 25 percent to 33 percent of historical wetlands may have been lost (Appendix 7 (Aquatic Plants (Wetland Systems))). However, regardless of the cause of floodplain isolation, the effects on the aquatic ecosystem and fish community are expected to be similar.

Side channels and other floodplain habitats are important habitats for fish (Reinhold et al. 2014), amphibians (Tockner et al. 2006), reptiles (Tornabene 2014, Jaeger et al., in review), birds (Jones 2014, Appendix 9 (Avian)), and other riverine animals, probably because of the habitat heterogeneity they provide. Side channels are often smaller and shallower, with slower current velocities, warmer water temperatures, and more biological productivity than main channels. Lateral habitats such as backwaters provide important habitat for larval and juvenile fishes (Sheaffer and Nickum 1986), as well as macroinvertebrates (e.g., aquatic insects and crustaceans; Sheaffer and Nickum 1986, Benke 2001), which contributes to fish recruitment and food sources in main channels. Therefore connectivity between main channel and side channel habitats is also important. For example, twice as many fishes were found in connected aquatic floodplain habitats than were found in disconnected habitats in the impounded lower Missouri River (Galat et al. 1998).

During runoff, seasonally inundated lateral habitats such as backwaters and side channels provide refuges for small fish (Brown and Hartman 1988; Pearsons et al. 1992; Aghostino and Zalewski 1995; Górski et al. 2011) because high water velocities can displace small fish, especially larvae (Ottaway and Clarke 1981; Ottaway and Forest 1983; Hjort et al. 1984; Harvey 1987; Sukhodolov et al. 2009). Floodplain habitats are important for fishes, particularly for spawning (Burgess et al. 2013) and for larval, juvenile, and small fishes (Scheurer et al. 2011). For example, Bigmouth buffalo spawn on inundated riparian vegetation in Yellowstone River floodplains and up to two weeks is needed for the eggs to hatch (Mike Ruggles, MFWP, personal communication). Certain fish species, such as Western Silvery Minnows have eggs and larvae that drift with the current during high flows (“pelagophils”). These species are particularly susceptible to flow regulation (Dudley and Platania 2007), because this behavior was an adaptation to natural flow regimes. The larvae of these species often settle out and develop in lateral floodplain habitats (Cowley 2006; Shirey et al. 2008; Scheurer et al. 2011; Magana 2012), therefore reducing the duration of floodplain inundation will cause larval mortality.

Side channels also provide fish habitat during base flow. Fish species richness was positively associated with increased habitat diversity in the upper Mississippi River during base flow conditions (Ellis et al. 1979; Koel 2004). Fish species richness (Koel 2004), sizes (Copp 1997), and abundances (Lyons 2005; Reinhold et al. 2014) can be distinct between side channel and main-channel communities. Moreover, the structure (e.g., composition and relative abundance) of the mainstem Yellowstone River fish community varied as a function of side channel availability during base flow (Reinhold et al. 2014).

In the Yellowstone River in Park County, side channels were probably important natural nursery areas for juvenile salmonids because other juvenile salmonid habitat was rare along the main-channel banks (Zale and Rider 2003). Moreover, side channels provide shallow, slow current velocity (SSCV; quantitative definitions of SSCV vary in different studies, but typical values are < 3.3 feet deep and < 1.5 feet/second) habitat during runoff when such habitat is negligible in the main channel. Although juvenile salmonid densities in side channels were not exceptionally high, juvenile salmonids, especially Mountain Whitefish, rapidly occupied side channels upon inundation. This suggests that when available, side channels are important habitats for juvenile salmonids.

On the upper Yellowstone River, Bowen et al. (2003a) demonstrated that SSCV area increases with increasing discharge and reaches a maximum during peak runoff. However, bank modifications such as levees and bank stabilization increase lateral river confinement which decreases side channel and overbank SSCV area, thereby reducing the overall amount of SSCV habitat available. SSCV availability was lowest in the Livingston reach (i.e., from just above Siebeck-9th Street Island to the Highway 89 Bridge (River Miles 500 to 504; Bowen et al. 2003a) and this reach generally had less SSCV attributable to side channels and overbank areas, particularly during bankfull flows (Bowen et al. 2003a). The Livingston reach also had the highest proportion of SSCV along modified banks, which may be important habitats for juvenile salmonids where such habitat is otherwise rare (Zale and Rider 2003). However, Zale and Rider (2003) also stress the importance of side channels as important juvenile salmonid habitat, and side channel area has probably been lost in the Livingston reach. Habitat modifications that reduce the frequency or duration of side channel inundation, or reduce side channel formation rates, would decrease juvenile salmonid habitat and possibly recruitment.

Side channels are also important spawning areas for Yellowstone Cutthroat Trout (DeRito et al. 2010). Although 75 percent of telemetered Yellowstone Cutthroat Trout spawned in tributaries, 23 percent spawned in side channels, compared to only 2 percent that spawned in main channels (DeRito et al. 2010). Standardized electrofishing surveys by Montana Fish, Wildlife & Parks have revealed declines in Yellowstone Cutthroat Trout numbers near Springdale, Montana from as high as 250 fish per mile in the 1990s to 45 fish total in 2005 in the five-mile long survey reach. Although the cause of this decline is not known with certainty, limited side channel habitat could be a factor (Scott Opitz; MFWP personal communication).

Side channels provided important habitat for the Yellowstone River shoreline fish community during runoff (Reinhold et al. 2014). Overall fish catch rates, catch rates of the most common species (Western Silvery Minnow, Longnose Dace, Flathead Chub, Sand Shiner, and Emerald Shiner; Figure 4-148), and number of fish species in fyke net catches (Figure 4-149) were generally greater in side channels than main channels during early and late runoff, but not during base flow. Overall fish catch rates in side channels were up to nine times higher compared to main channel catch rates (Figure 4-148). Fish community composition and relative abundance also differed between side channels and main channels during runoff, but not during base flow (Reinhold et al. 2014).

These results emphasize the importance of side channel habitats during high flows. Differences in main and side channel fish communities was probably due to the availability of SSCV habitats, rather than depth, velocity, and substrate where the nets were set, which were similar in main and side channel net sets. This conclusion is supported by modeling results that indicate that during runoff in the lower Yellowstone River, SSCV is limited and that it is primarily found in side channels (Bowen et al. 2003b).

The availability of side channels influenced the Yellowstone River fish community (Reinhold et al. 2014). During base flow, the catch rates of main channel fish communities varied in relation to the availability of side channels. Additionally, the relationships of fish communities to side channels were more consistent and widespread than the relationships to bank stabilization. Further, side channels and bank stabilization had differing and sometimes opposing influences on the structure of the fish communities. Side channel availability, measured at scales of up to one mile upstream and downstream of sample locations, was significantly associated with the composition and abundance of fish communities in both geologically constrained (bluff) pools and unconstrained (alluvial) and channel crossovers (Reinhold et al. 2014).

Reduced peak flows may alter the relationship between fish reproduction and hydrology. Hydrologic spawning cues may be disrupted or weakened. If fish spawn at a time that does not coincide with optimal levels of food for small fish, the result is a reduction in the number of young fish that survive each year (Humphries et al. 2013). Many fish species appear to time spawning events in relation to river flows such as the annual snowmelt peak flow. For example, Shovelnose Sturgeon spawned in the Marias River during two high-water years but not during a low-water year, despite suitable water temperatures. Therefore, it appeared that a discharge threshold was needed to provide a spawning cue for Shovelnose Sturgeon (Goodman et al. 2013). Similarly, Blue Suckers entered the Milk River from their overwintering habitat in the Missouri River when a threshold discharge of 1,000 cfs in May was reached in the Milk River (Fuller and Braaten 2012). It was unknown, but possible, that these movements were related to spawning.

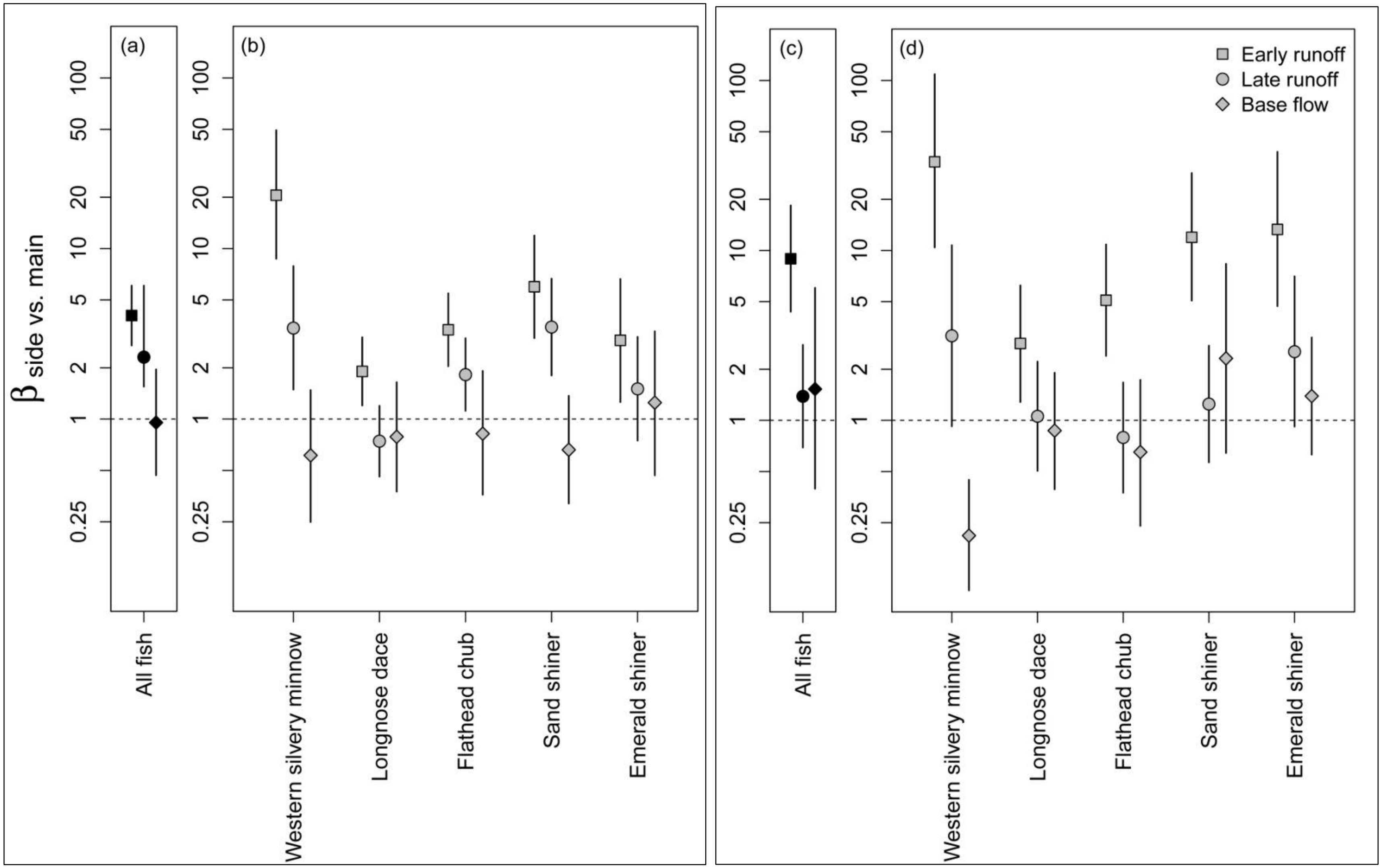


Figure 4-148 Estimated mean multiplicative differences (β) in side channel versus main-channel catches of fish captured in fyke nets during runoff and base flow in alluvial (a and b) and bluff river bends (c and d)

Note: *Estimates were generated from negative binomial regressions with offsets for sampling effort. Error bars represent 95% confidence intervals (from Reinhold et al. 2014)*

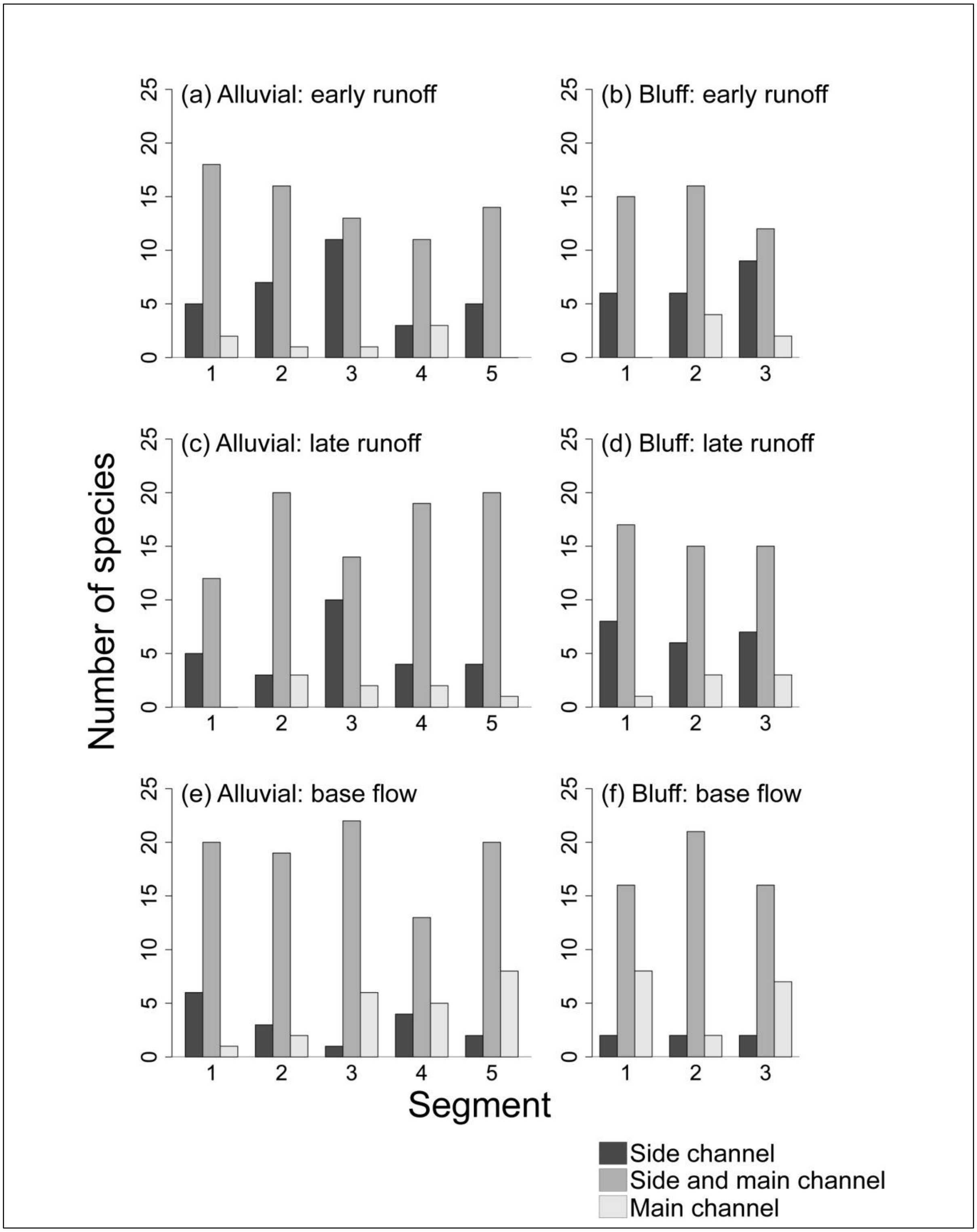
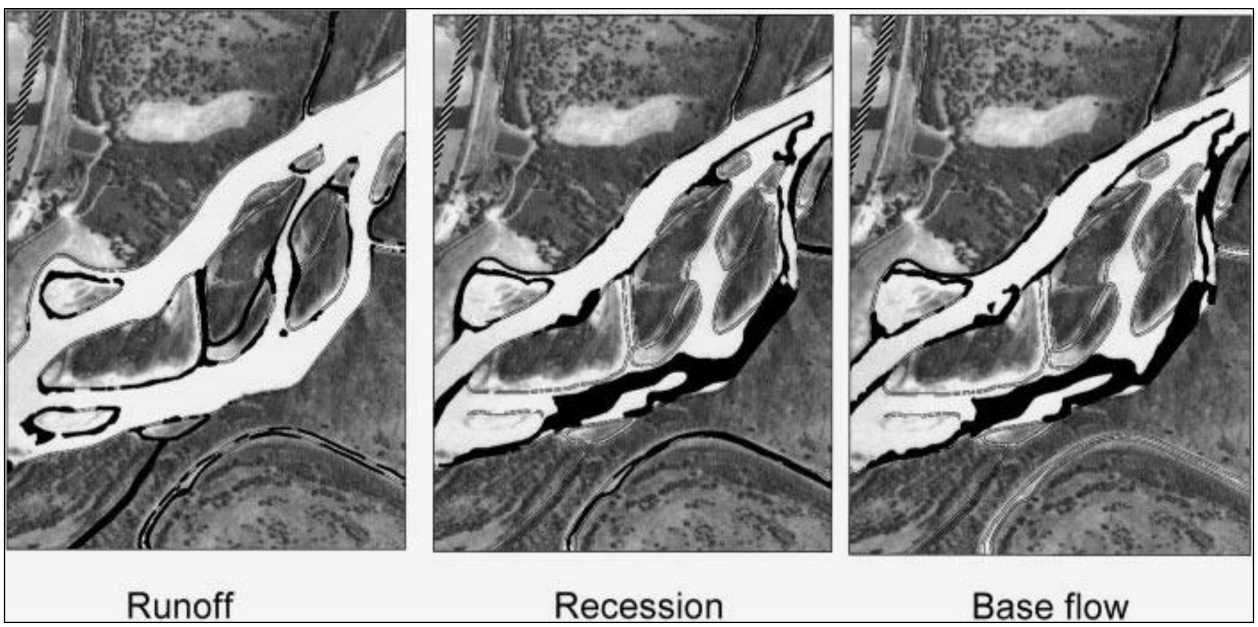


Figure 4-149 Habitat-specific comparisons of numbers of species for runoff and base flow conditions

Note: *Bar color indicates whether species were captured in side channels, main channels, or both (from Reinhold et al. 2014)*

Spiny Softshell turtles in the Yellowstone River preferred secondary channels in all seasons except winter, when they preferred bluff pools (Jaeger et al., in review). This pattern was also seen in the Missouri river in Montana where Spiny Softshells used shallow, slow, lateral habitats such as backwatered tributary mouths and inundated floodplains during all seasons except winter (Tornabene 2014). These habitats were typically near shore with shallow depth, zero to slow water velocity, fine substrates, and higher water temperatures than in the main river. Such areas seem to be important during this period because some turtles moved considerable distances, aggregated, and showed year-to-year fidelity to particular tributary confluences (Tornabene 2014). Spiny Softshells hibernate on the river bottom in winter, and select deeper water with moderate current velocities between the shoreline and the middle of the river, likely because they are not displaced by swift velocities, have adequate oxygen, and are deep enough to be safe from ice jams (Tornabene 2014). Bluff pools are slower and deeper than other pool types and probably provide adequate habitat for overwintering hibernacula.

Changes in amount and distribution of Shallow, Slow Current Velocity (SSCV) habitats were studied at three reaches on the lower Yellowstone River (Bowen et al. 2003b). During the rising limb of the hydrograph, SSCV patches were located primarily in side channels and back-flooded tributaries. At peak flow, flooding of vegetated islands and side channels provided organic material (leaf litter) to the river. Following peak flows and during base-flow periods, SSCV was found in the main channel and large side channels, and formed large patches (Figure 4-150). SSCV area during base flow was about double that available during runoff (Bowen et al. 2003b). Therefore, the amount of SSCV is limited during runoff, and it is found in side channels, which shows the importance of side channels in providing SSCV habitat.



Source: Bowen et al. 2003b

Figure 4-150 Distribution of SSCV habitat (black shading) during runoff, recession, and base flow in a portion of the Elk Island site on the Yellowstone River during the 1997 water year

The biological implications of these models is provided by Reinhold et al. (2014) who found that overall fish catch rates, catch rates of the most common species, and species richness in fyke net catches were generally greater in side channels than main channels during early and late runoff.

Reduced peak flows reduce the area and the duration of floodplain inundation. This floodplain isolation will reduce the amount of terrestrial energy (nutrients and material derived from terrestrial sources) reaching the river, thereby reducing overall productivity and fish food supply as outlined in the flood pulse concept (Junk et al. 1989). The ecological effects of floodplain isolation are expected to be increasingly important proceeding downstream on the Yellowstone River. According to the river continuum concept, rivers typically undergo a sequence of energy sources proceeding from the headwaters to the lower reaches (Vannote et al. 1980). In the headwaters, shading from riparian vegetation limits photosynthesis on the river bottom and most energy (organic materials such as leaves) comes from outside the stream (allochthonous energy). In the middle reaches, the stream is wider, relatively unshaded, and the water is clear, which allows for photosynthesis on the river bottom. Therefore in middle reaches most energy comes from within the stream (autochthonous energy), although energy also derives from drift from upstream. In the lower reaches of a river, turbid water limits in-stream photosynthesis, the floodplain is larger and more often inundated. Therefore most energy in the lower reaches comes from the floodplain (allochthonous energy) as well as from drift from upstream reaches.

Reduced peak flows will reduce the creation and maintenance of lateral habitats such as side channels and seasonal secondary channels (Appendix 4 (Geomorphology)). The two-year discharge is referred to as the channel-forming flow because it is the discharge most responsible for creation and maintenance of the river channel form and associated habitats such as side channels. The two to five year flow events are probably also the most relevant to fish reproduction, refuge habitat, and food supply because many of the fish in the Yellowstone River reproduce annually and have life spans less than five years (Brown 1971). Therefore, inundation of the two to five year floodplain is important to the extent that fish use the floodplain for spawning, juvenile fish habitat, or food supplies.

Reduced peak flows will likely reduce the amount of bank erosion and recruitment of large woody debris (LWD) to the river channel (Appendix 4 (Geomorphology)). The erosion rate of closed timber floodplain has declined in the most reaches of the Yellowstone River since the mid-1970s, resulting in an estimated 2,500 fewer trees being recruited into the river channel every year. Large woody debris influences channel geomorphology and is an important element of fish habitat because it provides cover and creates areas of deep scour. Large woody debris is also important for production of invertebrate prey items (Benke 2001), particularly in river habitats lacking hard rocky substrates such as in the Yellowstone River below Sidney, Montana, where sand is the primary substrate (Bramblett and White 2001).

Reduced Summer Low Discharge

Summer low flows have decreased on the Yellowstone River. For example, the summer low flow declined by about 48 percent from about 6,200 cfs to about 3,200 cfs at Miles City, Montana (Appendix 3 (Floodplain Connectivity)). Reductions in flows reduce the amount of aquatic habitat, bringing fish into closer proximity, thereby potentially increasing the rates of ecological interactions such as predation, competition, and transmission of disease or parasites. Reduction in flows will reduce river stage which affects the availability and suitability of fish habitats. For example, seasonally inundated side channels and floodplain habitats could be dewatered, thereby reducing the availability of important SSCV habitats, and reducing energy transmission between terrestrial and aquatic portions of the riverine ecosystem. Moreover, lower summer discharge allows encroachment of vegetation into side channels, which probably accelerates side channel loss through subsequent sediment capture.

Reductions in summer low flows may cause warmer water temperatures, which could have a number of influences on the fish community. Sublethal effects of increased temperatures on fish include altered spawning, growth, and resistance to diseases and parasites (Armour 1991). In the laboratory, juvenile Shovelnose Sturgeon growth was decreased and mortality was increased at temperatures above 24^{0} C

(Kappenman et al. 2009). When temperatures exceed the upper tolerance levels of fish species, fish kills can occur. Thermally-caused fish kills of primarily shovelnose sturgeon have occurred on the Des Moines River when water temperatures were exceedingly high (29-35ºC; Hupfield et al. 2014). Water temperatures in the lower Yellowstone River occasionally reach 29-30^0 C, suggesting that thermally induced fish kills may be possible if temperatures increase. Similarly, if water temperature increases beyond the thermal tolerance of any fish species occur along the length of the Yellowstone River, fish kills could result.

Fish distributions and relative abundance of both native and nonnative species may shift upstream as species seek their preferred temperatures. However, although water temperature may shift longitudinally, other ecosystem components such as channel slope, riverbed substrate, position of spawning tributaries, and structures that block fish movements such as diversion dams will not, and may preclude simple longitudinal shifts in the distributions of Yellowstone River fish in response to temperature changes. The relative abundance of fish species may change longitudinally if water temperatures increase. For example, fish species such as Shorthead Redhorse and Goldeye that are currently present in the coldwater zone, but are more abundant downstream in warmer waters may increase their abundance in the present coldwater zone. Smallmouth Bass, which were stocked in the Tongue River below the Tongue River reservoir in the late 1960s, as well as in the lower Bighorn River between 1986 and 1992 (Ken Frazer, MFWP, personal communication) are now established in the Yellowstone River from above the mouth of the Powder River to Billings (Montana Fish, Wildlife & Parks 2015). However, Smallmouth Bass appear to be expanding their range in the Yellowstone River, and have recently been documented as far upstream as the mouth of the Shields River (Scott Opitz, MFWP, personal communication). This apparent upstream expansion of Smallmouth Bass may be related to warming water temperatures. Smallmouth bass are visual predators, are strongly associated with large rock substrate (Todd and Rabeni 1989), prefer water temperatures generally less than about 70^0 F, and spawn primarily at temperatures of 61^0-65^{0}F (Scott and Crossman 1973). The longitudinal distribution of smallmouth bass will be influenced by gradients in water clarity, substrate, and temperature. Currently, the lower river is probably too turbid, warm, and lacking in large rock substrate for smallmouth bass, whereas the upper river has clear water and large substrate but is too cold. Therefore if water temperatures increase, smallmouth bass may become established farther upstream in the Yellowstone River.

The oxygen balance in a river is controlled by water temperature, atmospheric pressure, diffusion, turbulence, photosynthesis, and in-stream biological respiration. Warmer water contains less oxygen, however oxygen rarely limits fish survival in rivers, except in very warm, heavily polluted, or highly productive rivers. There is little information on the oxygen tolerances of the fish community in the Yellowstone River, however species such as Fathead Minnow, Longnose Dace, Sand Shiner, Emerald Shiner, White Sucker and Channel Catfish, tolerate oxygen levels as low as 2.0 mg/L (Doudoroff and Shumway 1970; Matthews and Manness 1979; Smale and Rabeni 1995), which is lower than normally found in rivers. Further, it is very unlikely that the water will warm enough to approach these levels because even at 113^0 F, the oxygen saturation of water is almost 6 mg/L. Salmonids are generally less tolerant of low oxygen levels than other fish families such as minnows, suckers, and catfish, therefore increased water temperature and reduced oxygen probably has the most potential to affect salmonids in the present coldwater zone of the river. Although it is difficult to make definitive predictions, such effects may be sublethal and involve reduced salmonid metabolism, activity, growth, or distribution. Angling mortality for salmonids generally increased with water temperatures above 20^o C (Boyd et al. 2010). Montana Fish, Wildlife & Parks has enacted fishing restrictions in the coldwater zone of the river in the past to reduce potential angling-related mortality on salmonids (Scott Opitz, MFWP, personal communication).

Altered thermal regimes may change ecosystem productivity and lead to altered food webs. Reduced flow volumes will concentrate pollutants and may thereby affect fish. Perhaps most importantly, reductions in flows may increase the human demands for water relative to supply and thereby lead to further reductions in flow.

Increased Fall and Winter Low Discharge

The typical fall and winter low flow on the Yellowstone River has increased. For example, the winter low flow increased by about 60 percent from about 2,000 cfs to about 3,200 cfs at Miles City, Montana such that average winter flow is similar to the summer low flow (Appendix 4 (Geomorphology)). Increases in fall and winter discharges alter the natural pattern of discharge to which native fishes have adapted. It is difficult to determine thresholds of change in discharge and to predict how this may affect fish communities, however the scientific literature indicates that the greater the hydrological change, the higher the ecological risk (Poff and Zimmerman 2010). Higher fall and winter discharges will increase volume of water in the river, and likely create greater depths and current velocities, thereby altering overwintering habitats for fish and Spiny Softshells. Such changes may increase the energy expenditures for fish and Spiny Softshells during periods of temperature-regulated low metabolism, thereby possibly reducing energy reserves of fish and turtles. Changes in fall and winter stream discharge may alter normal patterns of ice formation, breakup, and jamming with unknown effects on overwintering fish and turtles. Increased ice jamming could increase the risk of turtle and fish mortality caused by ice scour.

In the middle and lower Yellowstone River, historically there was a small peak in the hydrograph caused by low-elevation snowmelt that occurred in March and early April, often referred to as the “prairie peak.” The overall increases in low flows during March and April have dampened the prairie peak such that it is less of a peak under current hydrological conditions (Appendix 2 (Hydrology)). Although the prairie peak was much smaller than the peak mountain snowmelt discharge that occurred in June, it may have been an important cue for fish spawning or movement in the Yellowstone River, and in tributaries such as the Bighorn, Tongue and Powder rivers. For example, Sauger spawning in the lower river occurs in this general timeframe. Jaeger et al. (2005) considered the Sauger spawning season on the Yellowstone River near Miles City to be March 15-May 15, based on collection of female Sauger that were gravid, running eggs, or spent, and spawning condition of Sauger captured in standardized sampling by Montana Fish, Wildlife & Parks indicates that Sauger spawning begins in April (Caleb Bollman, 2015, personal communication). Other Yellowstone River fishes exhibit considerable movement rates during spring when the prairie peak occurs. Burbot, Channel Catfish, Shovelnose Sturgeon, and Spiny Softshells all had movement rates during spring that were not significantly different than movement rates during runoff (Jaeger et al. in review). The prairie peak in the Powder River in 1938-1967 occurred in early April, but since 1968. It has occurred in mid-March, which is about two weeks earlier (Karin Boyd, Applied Geomorphology, personal communication). This change may alter cues for fish movement or spawning in the Powder River and in the Yellowstone River below the confluence of the Powder River. Changes in the prairie peak may disrupt or weaken hydrologic spawning cues, with uncertain consequences for survival of fish early life history stages.

Reduced Hydrograph Rise and Fall Rates

The rise and fall rates on the Bighorn River have been markedly affected by Yellowtail Dam as described in Section 4.3. Rise and fall rates have been reduced on the Bighorn River, resulting in a substantial dampening of the natural hydrograph that is transmitted to the Yellowstone River downstream at least as far as Miles City, although the impact is markedly lower than on the Bighorn River itself.

Altered rise and fall rates of peak runoff may alter the relationship between fish reproduction and hydrology. As discussed above, fish spawning events may be cued by hydrologic conditions such as the annual snowmelt peak flow. Reduced rise and fall rates may disrupt or weaken hydrologic spawning cues, and cause mismatch of reproduction and habitat, with uncertain consequences for survival of fish early life history stages. Altered timing between flows and fish reproduction may result in changes in fish species distribution and abundance.

Reduced Discharge from the Bighorn River and other Tributaries

Large reservoirs, irrigation withdrawals, and small dams such as stock ponds all contribute to the reduction of discharge from Yellowstone River tributaries. Although the Yellowstone River mainstem is unimpounded, 31 percent of its drainage basin lies upstream of dams (Koch et al. 1977). Dams fragment fish populations by preventing fish movement and also alter ecological conditions in the dammed river as well as in the receiving Yellowstone River. The serial discontinuity concept (Ward and Stanford 1983) conceptualizes the ecological effects of mainstem dams based on their placement along the longitudinal river continuum (Vannote et al. 1980). A dam placed on the lower reaches of a mainstem river is predicted to shift primary production, nutrient levels, turbidity, substrate size, and water temperatures to those found farther upstream on an undammed river (Ward and Stanford 1983).

Yellowtail Dam was installed on the lower reaches of the Bighorn River in 1967; this dam transformed a sediment-laden, warmwater prairie river into clear, cool, blue-ribbon tailwater trout fishery. This transformation in turn affected the Yellowstone River by reducing sediment load, turbidity, peak discharge and scouring flows, and causing cooler summer and warmer winter water temperatures, as well as preventing long-distance fish movements between Yellowstone and Bighorn rivers. Reductions in sediment inputs can cause channel incision (Simon and Darby 1999) and consequently side channel dewatering (Wohl 2004). The largest reductions in braiding since the 1950s occurred between the Bighorn and Powder rivers (Thatcher and Boyd 2007). Moreover, unvegetated bars were historically common on the Yellowstone River below the Bighorn River (Koch et al. 1977; Silverman and Tomlinsen 1984), but many of these bars have been replaced by vegetated islands (Thatcher et al. 2009;). Flow regulation at Yellowtail Dam on the Bighorn River has resulted in a reduction of flood magnitudes on the Yellowstone River below the confluence, and dampened the hydrograph on the Yellowstone River by reducing daily rates of discharge rise and fall at least as far downstream as Miles City (Section 4.3).

The Tongue River Reservoir and dam modified ecological conditions in the Tongue River and the receiving Yellowstone River. However, following the principles of the serial discontinuity concept (Ward and Stanford 1983), the ecological effects of the Tongue River dam may have been less severe than those caused by the Yellowtail Dam on the Bighorn River. Specifically, about one-third of the Tongue River drainage basin is upstream of the Tongue River Dam, whereas about four-fifths of the Bighorn River basin is upstream of Yellowtail Dam. Therefore, the transformation of the Tongue River was likely less severe because the dam is located nearer to the headwaters of the Tongue River. Nonetheless, altered hydrology on the Tongue River has affected the ecology of the Tongue and its ecological connectivity with the Yellowstone River.

Installation of dams on the Bighorn and Tongue rivers has fragmented these two rivers and also prevents long-range movements between the Yellowstone River and those tributaries. By removing the natural sediment load and turbidity, these two dams have also reduced the ecological suitability of the Bighorn and Tongue rivers as well as the Yellowstone River below the confluence of the two tributaries for native turbid water fish. This type of human influence has been documented in Wyoming where a group of fishes adapted to high turbidity including Shovelnose Sturgeon, Flathead Chub, Goldeye, Plains Minnow, Western Silvery Minnow, and Sturgeon Chub (see Figure 4-151) have been disappearing from Wyoming rivers that are heavily modified by reservoir construction.

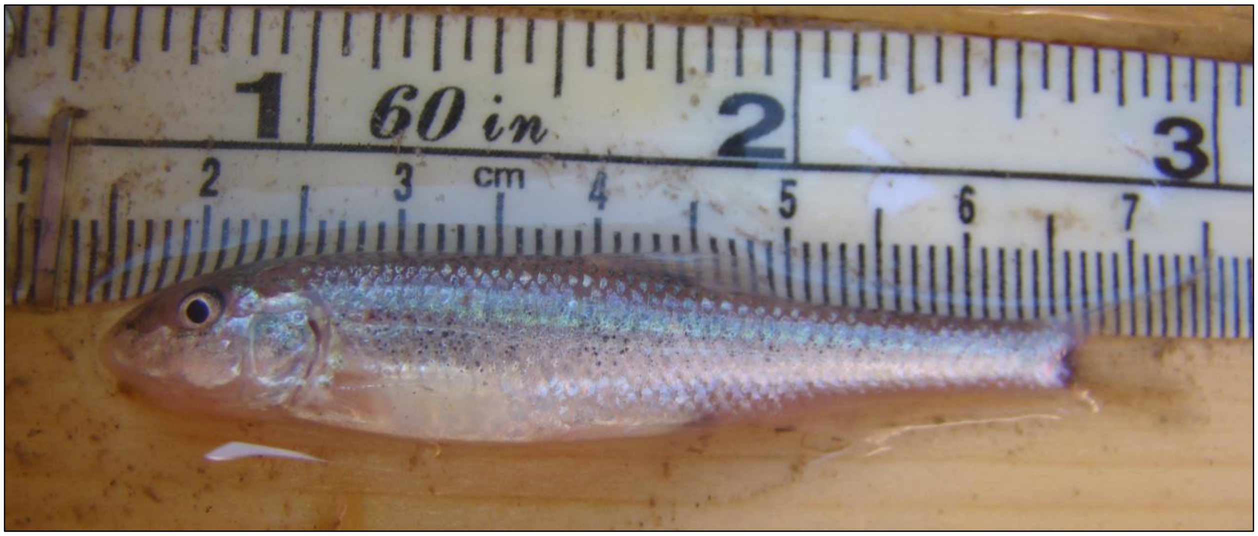


Figure 4-151 Sturgeon Chub (Photo Reinhold 2010)

Of these species, only Flathead Chub appear to be secure in the Bighorn River basin (Wyoming State Wildlife Action Plan 2010). Shovelnose sturgeon were extirpated from the Bighorn River in Wyoming, probably because their movements were blocked by Yellowtail Dam, and a reintroduction program for them was initiated in 1996 in the Bighorn River in Wyoming (Wyoming State Wildlife Action Plan 2010). Goldeye, Plains Minnow, Western Silvery Minnow, and Sturgeon Chub formerly occupied the Bighorn River, but are now apparently extirpated there (Quist et al. 2004; Wyoming State Wildlife Action Plan 2010). Moreover, Sturgeon Chub populations in the Yellowstone River almost certainly extended upstream to the mouth of the Bighorn River, however no Sturgeon Chub were captured above the Tongue River during extensive sampling (Duncan et al. 2012; Reinhold et al. 2014). Sauger in the Bighorn River basin in Wyoming are now isolated from Yellowstone River populations (McMahon and Gardner 2001). Sauger have also declined in the Yellowstone River in the vicinity of and below the confluence of the Bighorn River, probably due to reduced temperatures, reduced sediment yield and associated turbidity, dampened spring peak flows that cued upstream migration, diversion dams, and habitat changes (McMahon and Gardner 2001). Reduced turbidity may also be more suitable for Walleye than for the native turbidity-loving Sauger. The Sauger population that formerly occurred in the Bighorn River below Yellowtail Dam is now thought to be extirpated (Mike Ruggles, MFWP, Personal Communication). The population of Sauger upstream of Bighorn Reservoir in Wyoming is extant, but is genetically different than Yellowstone River Sauger (Bingham et al. 2011).

Flow regulation by Yellowtail Dam on the Bighorn River has caused increased floodplain isolation (Appendix 3 (Floodplain Connectivity)). Specifically, upstream of the Bighorn River confluence, typically less than 20 percent of the historical 5-year floodplain has been isolated; downstream of the confluence over 40% of the historical 5-year floodplain is now inaccessible by a 5-year flood. Isolation of the 2-year floodplain has resulted in reduced seasonal high flow channel activation during that event. The extent of 2-year floodplain isolation has been most significant between the confluences of the Bighorn and Tongue Rivers, where the developed 2-year inundation footprint is on the order of 40 percent smaller than that under undeveloped conditions. The effects of floodplain isolation on fish are discussed above.

Impoundments on the Bighorn and Tongue rivers probably influence shallow, slow current velocity (SSCV) habitats and vegetated floodplain inundation on the Yellowstone River. Therefore, effects of Yellowstone River tributary impoundment may be similar to, but less extreme than those seen on the Missouri River (Bowen et al. 2003b). Specifically, the present-day Yellowstone River may have less variation in mean SSCV patch size, patch density, and location of patches, as well as less area of inundated woody vegetation than the pre-settlement Yellowstone River. Bank stabilization and construction of levees and floodplain dikes have probably also reduced Yellowstone River SSCV dynamics and floodplain interaction. Because the Yellowstone River biota evolved in a setting of snowmelt-driven hydrology and a river corridor absent of dikes, levees, and bank stabilization, it is reasonable to assume that human alterations to natural river processes have affected the riverine ecosystem and its native fishes.

Reduced discharge in tributaries may alter cues for fish movement between tributaries and the mainstem, reduce tributary habitat volume and quality, and reduce within-tributary movement. Reductions in tributary inflows will probably reduce fish movement between tributaries and the Yellowstone River, particularly in dammed tributaries such as the Bighorn and Tongue rivers. Movements between rivers and tributaries often coincide with hydrological cues such as high water periods. Reduced discharge from tributaries probably alters spawning cues for resident fish in the tributary as well as for fish entering tributaries from the Yellowstone River for spawning. In much of eastern Montana, prairie stream tributaries are intermittently dry and limits fish movement during dry periods. Reduced tributary discharge would further reduce intermittent tributary fish movement. Connectivity between mainstem rivers and tributaries supports higher fish species richness in both the mainstem river and the tributary (Schaefer and Kerfoot 2004).

The Shields, Boulder, Clarks Fork, and Stillwater rivers as well as other smaller tributaries are used by trout for spawning (Scott Opitz, 2015, MFWP, personal communication). Introduced Rainbow Trout threaten native Yellowstone Cutthroat Trout by hybridization. Altered hydrology or warming of these and other tributaries may alter their suitability as spawning habitats and affect survival rates of young fish. Yellowstone Cutthroat Trout and Rainbow Trout in the Yellowstone River Basin use many of the same tributaries for spawning, but a study conducted in 2001-2003 indicated that hybridization risk is reduced because Rainbow Trout and hybrids spawned in April and May whereas Yellowstone Cutthroat Trout spawned in June and July (DeRito et al. 2010). However, earlier and lower runoff, and potentially warmer temperatures may reduce temporal separation of Rainbow and Yellowstone Cutthroat Trout and lead to higher rates of hybridization. Such a compression of spawning periods has been observed by fish biologists in recent years (Scott Opitz, MFWP, personal communication). A similar loss of temporal separation in spawning periods for Walleye (April-May) and Sauger (May-June) could occur and increase hybridization between these two species (Mike Ruggles, MFWP, personal communication).

4.9.4.2 Altered Geomorphology

The geomorphology of the Yellowstone River has been changed by flow alterations, dikes and levees, land use conversions, and bank armor (Appendix 4 (Geomorphology)). The floodplain of the Yellowstone River has become more isolated over time. Over 21,000 acres of 100-year floodplain area have been isolated due to physical encroachments, agricultural development, and hydrologic alterations. Upstream of the Bighorn River confluence, typically less than 20 percent of the historical 5-year floodplain has been isolated; downstream of the confluence over 40% of the historical 5-year floodplain is now inaccessible by a 5-year flood. Isolation of the 2-year floodplain has resulted in reduced seasonal high flow channel activation during that event. The extent of 2-year floodplain isolation has been most significant between the confluences of the Bighorn and Tongue Rivers, where the developed 2-year inundation footprint is about 40 percent smaller than that under undeveloped conditions.

Altered geomorphology contributes to floodplain isolation, and has associated ecological consequences. The connection of a river with its floodplain and with other lateral habitats such as side channels is an integral part of a riverine ecosystem (Junk et al. 1989). Floodplain isolation reduces terrestrial inputs to the river's food web, reduces the area, creation, and maintenance of lateral off-channel habitats, reduces the availability of shallow, slow current velocity refuges during high flows, increases current velocities in main channels, and reduces overall aquatic habitat diversity. As discussed previously, altered hydrology also isolates floodplains, however, the effects on the riverine ecosystem in general and on fish communities specifically are expected to be the same regardless of the cause of floodplain isolation.

The area of isolated floodplain increases longitudinally proceeding downstream on the Yellowstone River; this pattern is similar for the 100-year, the 5-year, and the 2-year floodplains (Appendix 4 (Geomorphology)). This is not surprising because the floodplain area generally increases going downstream, so there is more floodplain to become isolated. There is an increase in floodplain isolation below the Clarks Fork and a more substantial increase below the Bighorn River. The largest single cause of floodplain isolation is agriculture, which accounts for 42 percent of 100-year floodplain isolation.

The longitudinal increase in floodplain isolation corresponds to the importance of the floodplain to the Yellowstone River ecosystem. According to the river continuum and flood pulse concepts, the amount of riverine productivity attributable to the floodplain increases in the lower reaches of a larger river. In its lower reaches, the Yellowstone River has developed a larger floodplain (except in geologically confined reaches) where under pristine conditions, the floodplain contributed heavily to riverine productivity and habitat diversity. However, these are generally the same reaches where floodplain has become most isolated. Although it is difficult to quantify the effects of this floodplain isolation in terms of fish distribution and abundance, professional judgment indicates that the impact of lost floodplain has been substantial. Moreover, because fish species richness increases downstream, more fish species are affected by floodplain isolation in the lower reaches of the Yellowstone River.

4.9.4.3 Bank Stabilization

The alteration of large rivers by structures such as bank stabilization results in changes in riverine habitats such as main-channel bed degradation, channel width reduction, and increased stream gradient (Stern et al. 1980; Heede 1986; Shields et al. 1995). Moreover, bank stabilization reduces floodplain connectivity and natural riverine processes such as lateral channel migration, the formation of backwaters, braids, and side channels (Leopold 1964; Stern et al. 1980; Shields et al. 1995; Schmetterling et al. 2001; Auble et al. 2004; Florsheim et al. 2008), and recruitment of large woody debris (LWD).

Bank stabilization was associated with decreases in fish abundances in some rivers (Buer et al. 1984; Li et al. 1984; Swales et al. 1986; Knudsen and Dilley 1987; Thurow 1988; Beamer and Henderson 1998; Peters et al. 1998; Oscoz et al. 2005) increases in other rivers (Knudsen and Dilley 1987; Binns 1994; Binns and Remmick 1994; Avery 1995; White et al. 2010), or had no effect (Madejczyk et al. 1998; McClure 1991). Similarly, fish species richness was decreased (Oscoz et al. 2005), increased (White et al. 2010), or unchanged (Madejczyk et al. 1998) in stabilized reaches. Changes in fish community structure (Eros et al. 2008; Madejczyk et al. 1998) or size-class distributions (Eros et al. 2008) have occurred in bank-stabilized reaches. Thus, bank stabilization has uncertain and possibly multifaceted consequences for fish communities.

The discrepancies in the findings of previous studies may result from differences in rivers. In artificially or naturally homogenous rivers, bank stabilization may provide habitat diversity that is otherwise lacking (Schmetterling et al. 2001; Zale and Rider 2003), and cause localized increases in fish density and species richness. Conversely, in unaltered or relatively heterogeneous rivers, moderate amounts of bank stabilization may have little or no effect on the fish communities. Moreover, with the exception of studies by Zale and Rider (2003) and White et al. (2010), all studies of the effects of bank stabilization in large rivers have been conducted in regulated rivers (Michny 1988; Garland et al. 2002; Eros et al. 2008;

Schloesser et al. 2012) where the effects of bank stabilization may be confounded by or interact with the effects of dams.

Zale and Rider (2003) compared juvenile salmonid use of altered bank habitats to use of natural, unaltered bank habitats on the upper Yellowstone River. Juvenile salmonid use of barbs and jetties was similar to that of natural outside bends, and use of riprap sections was higher than that of natural outside bends. Juvenile salmonid recruitment from main-channel habitats was probably not negatively affected by bank stabilization. However, the amount of recruitment from main-channel habitats relative to recruitment from other areas such as side channels, backwaters, and tributaries is not known. Reductions in the frequency or duration of side channel inundation, or side channel formation rates, would probably decrease juvenile salmonid habitat and possibly decrease juvenile salmonid survival.

Bowen et al. (2003a) evaluated the relationships between the level of channel modification (bank stabilization structures (e.g., riprap, jetties, barbs, levees) and shallow, slow current velocity (SSCV) habitats on three reaches (2.6 to 3.9 miles in length) of the Yellowstone River in Park County, Montana. This study demonstrated that SSCV area increases with increasing discharge and reaches a maximum during peak runoff. It appears that the juvenile salmonid's needs and the physical habitat conditions are synchronized because the highest abundance of newly-hatched salmonids, which are small and weak swimmers compared to adults, coincides with high SSCV habitat availability in side channels and overbank areas, when main channel habitats have the highest prevalence of fast and deep water. However, bank stabilization and levees increase lateral river confinement, decrease side channel and overbank SSCV area, thereby reducing the overall amount of SSCV habitat availability.

SSCV availability was lowest in the Livingston reach (i.e., from just above Siebeck-9th Street Island to the Highway 89 Bridge (River Miles 500 to 504; Bowen et al. 2003a), which was also the reach that was the most anthropogenically modified. The Livingston reach is naturally confined on the east bank by a high valley wall and confined on the west bank by levees and riprap. As a result, the Livingston reach had the lowest overall SSCV area, because this reach generally had less SSCV attributable to side channels and overbank areas, particularly during bankfull flows. The Livingston reach also had the highest proportion of SSCV attributable to stabilized banks, which may be important habitats for juvenile salmonids (Zale and Rider 2003). However, Zale and Rider (2003) also stress the importance of side channels as important juvenile salmonid habitat, and side channel area has probably been lost in the Livingston reach. Bank stabilization structures probably also reduce large woody debris recruitment and retention; large woody debris provides modest amounts (8 percent to 22 percent of total) of SSCV during high flows.

The inference of Bowen et al. (2003b) with regard to effects on fish is based on the assumption that SSCV is an important habitat component for juvenile salmonids, and in particular newly-hatched salmonids during runoff. Substantial basis for this assumption exists in the literature; moreover the fisheries research project (Zale and Rider 2003) that accompanied this work supports the assumption in this setting. As noted by the authors, “Effects of reduced juvenile abundances during runoff on adult numbers later in the year will depend on (1) the extent of channel modification, (2) patterns of fish displacement and movement, (3) longitudinal connectivity between reaches that contain refugia and those that do not, and (4) the relative importance of other limiting factors.”

Reinhold et al. (2014; Chapter 2) examined the relationships among the frequency of floodplain dikes and linear bank stabilization and areal changes in side channels from the 1950s to 2001 on the mainstem Yellowstone River from its confluence with the Clarks Fork Yellowstone River near Billings, Montana, downstream to its confluence with the Missouri River. The loss in side channels exceeded the gain in side channels from the 1950s to 2001. Sixty-seven side channels were lost, 39 side channels were gained, and 91 remained stable. Floodplain dikes that blocked side channels were correlated with the net loss of

1.2 square miles of side channel area, which represented a 10.4 percent net loss in side channel area from the 1950s to 2001 indicating that side channels have been lost on the Yellowstone River due to dikes that block scouring flows in side channels. However, linear bank-stabilization (e.g., riprapped banks) extent did not correlate with side channel loss. This lack of correlation may be because linear bank stabilization effects on side channels are less direct than blocking side channels with dikes, because the extent of pre-1950 bank stabilization could not be estimated, or because existing linear stabilization in the Yellowstone River is not extensive enough to cause large-scale side channel loss. The effect that this loss of side channels has had on Yellowstone River fish populations is not known, however, side channels are highly productive habitats that are heavily used by small fish, particularly during runoff (Reinhold et al. 2014).

Reinhold et al. (2014; Chapter 4) examined the relationships of main-channel fish communities to bank stabilization and side channels in five segments of the Yellowstone River from near Billings, Montana, downstream to its confluence with the Missouri River. Fish community responses to side channels were more consistent and widespread than the responses of the fish community to bank stabilization; more fish species positively correlated with side channels than with bank stabilization. Both bank stabilization and side channels influenced some parts of the fish community, and bank stabilization and side channels were often associated with shifts in the identity and abundance of the fish communities in different or opposite directions. This suggests that bank stabilization has caused changes in the fish communities of the Yellowstone River, and that side channels influence the fish community to remain more similar to the pre-stabilization condition. Therefore, preserving or restoring side channels and minimizing bank stabilization will likely help preserve the Yellowstone River fish community. Moreover, the strengths of the relationships among fish communities, bank stabilization, and side channels depended on the spatial scale at which they were measured; suggesting that bank stabilization and side channels influenced fish across multiple spatial scales. Stabilized alluvial pools were significantly deeper than their non-stabilized counterparts, probably because bank stabilization halted lateral channel migration but increased vertical scour. Conversely, in bluff pools, depths were similar at stabilized and reference sites probably because lateral channel migration and scour are in relative equilibrium at erosion-resistant bluff pools. Therefore, a potential mechanism whereby bank stabilization influences fish communities is by creating deeper pools at stabilized alluvial river bends.

Duncan et al. (2012) detected a few differences in fish catch rates between stabilized and non-stabilized pool types in the Yellowstone River. Catch rates for Sand Shiners in bluff, terrace, and alluvial pools were significantly higher than in some stabilized pool types. Catch rates for Flathead Chub in bluff and terrace pools were significantly higher than in stabilized alluvial pools. Stabilization may therefore reduce local Sand Shiners and Flathead Chub abundance.

Jaeger et al. (in review) examined preference of Blue Sucker, Burbot, Channel Catfish, Shovelnose Sturgeon, and Spiny Softshell for habitat types in the Yellowstone River based on geomorphic function (e.g., pool, crossover, secondary channel) and bank material (e.g., bedrock, terrace, alluvium, riprap). Pool types were bluff (the pool contacted bedrock valley margin), terrace (the pool contacted geologic terrace valley margin), alluvial (the pool did not contact bedrock or terrace valley margin), riprap bluff, riprap alluvial, crossover, and secondary channel. Blue Suckers, Channel Catfish, and Shovelnose Sturgeon, did not prefer or avoid stabilized (riprap) habitats in any season. During spring, runoff, and summer, Burbot preferred bluff and riprap alluvial pools, and during winter, Burbot preferred riprap alluvial pools. Burbot use of stabilized and bluff pools is probably because Burbot are often associated with large substrates (Edsall et al. 1993; Dixon and Vokoun 2009; Eick 2013) which accumulates in bluff pools and is also present along riprapped banks. Spiny Softshells (see Figure 4-152) avoided riprap alluvial pools in all seasons, perhaps because preferred secondary channels in all seasons except winter when they preferred bluff pools.

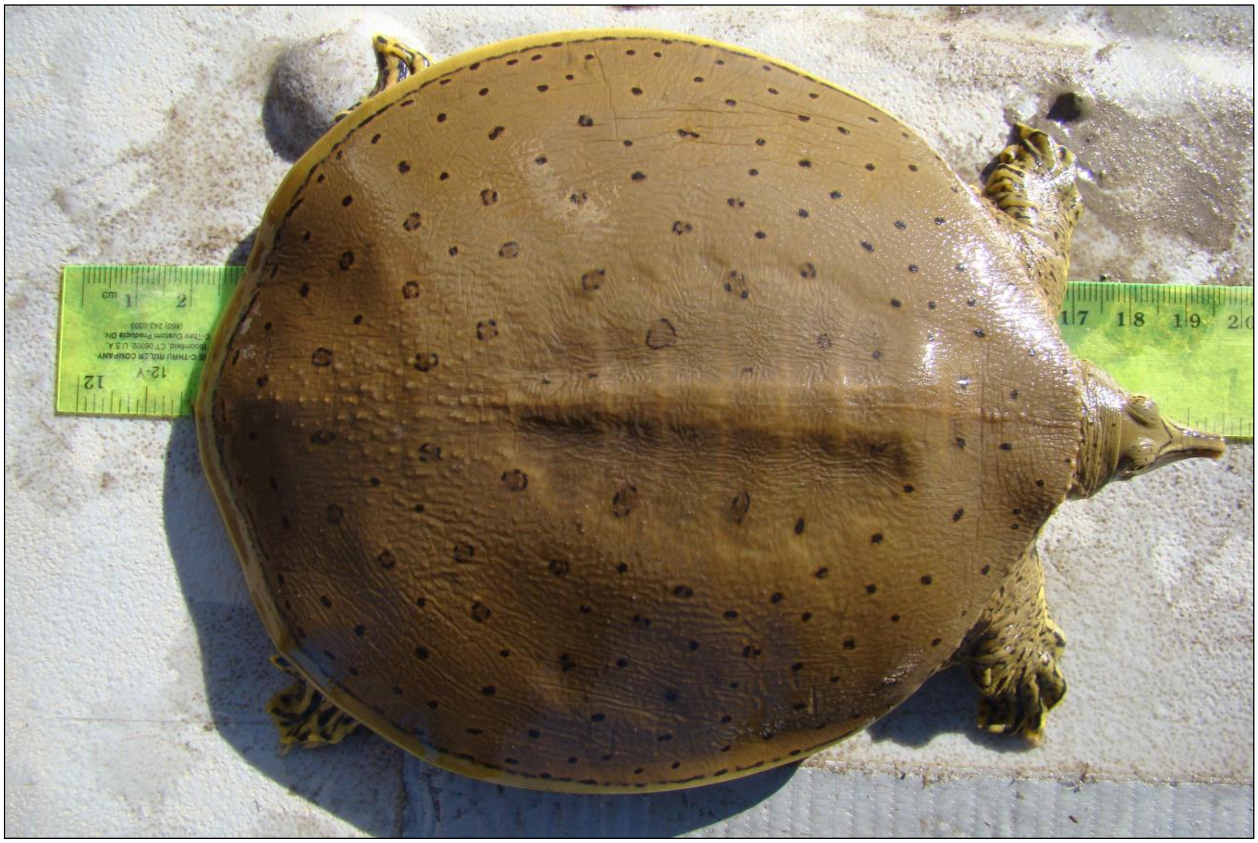


Figure 4-152 Spiny Softshell turtle (Photo Reinhold 2010)

4.9.4.4 Altered Riparian Vegetation and Wetlands

Riparian vegetation communities and wetlands provide important ecological services that benefit the natural function of the river, including dissipation of flood energy, trapping sediments, filtering nutrients and other pollutants, providing fish and wildlife habitat, and contributing to the biological productivity of the aquatic ecosystem. These functions include the connection of the aquatic and terrestrial communities as described by the river continuum concept (Vannote et al. 1980) and the flood pulse concept (Junk et al. 1989). The extent and distribution of riparian vegetation and wetlands along the Yellowstone River are strongly influenced by natural channel morphology, particularly the degree of channel confinement and floodplain turnover.

Overall, riparian areas have not changed much in cumulative extent, however individual reaches have lost or gained riparian vegetation area (Appendix 6 (Terrestrial Plants (Riparian Systems)). A noteworthy trend is that below the Bighorn River, reduced hydrologic scour caused by hydrologic changes from Yellowtail Dam has allowed encroachment of woody vegetation onto formerly open gravel and sand bars. Russian olive and saltcedar have become established in riparian forests and replacement of cottonwoods may decrease recruitment of large woody debris (LWD), in part because beaver preferentially remove cottonwoods. Riparian vegetation and wetlands have become isolated as described above for floodplain isolation. Alterations in distribution, extent, composition, and turnover of riparian areas and wetlands likely affect fish communities by changing the natural flow of energy and biota between floodplains and main river channels. Riverine wetlands provide important fish habitat, particularly during high river discharge.

4.9.4.5 Altered Land Use

Land use has changed along the Yellowstone River and is described in Appendix 1 (Land Use). Although most of the land use along the Yellowstone River remains in agriculture, increases in exurban and urban land uses have occurred, particularly in Park County and in the Billings area. The effects of this land use change on water quality and fish habitat have not been quantified. However, increased nutrients, turbidity, and pollution associated with land use changes may affect fish in the upper river, where clean, clear, and relatively low-nutrient waters represent the natural conditions to which the coldwater fish community are adapted. Increased impervious surfaces in urban areas increases quantity of stormwater runoff, and increases pollutant loads in nearby streams (Brabec et al. 2002) and likely occurs in tributaries of the Yellowstone River in and near Billings. This may affect the quality of habitat and water for fish. Conversion of riparian forest to agricultural land alters the natural erosion rates and lateral movement of the river channels because erosion rates are higher in cleared agricultural lands than in riparian river bottoms. Land conversion away from riparian forest also reduces LWD recruitment to the river; LWD is important fish and invertebrate habitat.

4.9.4.6 Altered Connectivity

Connectivity in riverine ecosystems occurs on four dimensions: longitudinal (upstream-downstream), lateral (river channel-floodplain), vertical (river channel-ground water), and temporal (time, from behavioral response time to evolutionary time; Ward 1989). Longitudinal connectivity is a central factor shaping riverine biological communities (Cote et al. 2008). Connectivity between the mainstem river and its tributaries is also important (Duncan et al. 2012), because many fish species use tributaries during some part of their life history.

4.9.4.7 Longitudinal Connectivity

Longitudinal connectivity is a fundamental feature of rivers and fish evolved in mostly unfragmented rivers. The importance of longitudinal connectivity of a river is a central tenet in river ecology (Vannote et al. 1980; Fausch et al. 2002), and loss of connectivity has been implicated in the decline of riverine fishes worldwide. The mainstem Yellowstone River has been longitudinally fragmented by six diversion dams. The diversion dams typically span the entire width of the river, and range from 1 to 3.2 m in height (Helfrich et al. 1999). Side channels are present at Intake, Ranchers Ditch, Waco-Custer, and Huntley Diversion dams and these probably allow an unknown amount of fish passage when discharge is sufficient. A limited amount of upstream fish passage (10 species) has been documented at all six dams, although it is not usually know whether a fish passed over the dam or via the side channel (at those dams with side channels), or how many fish passed.

Although some fish species can pass each of the diversion dams under certain conditions, the extent thereof, usually the discharge conditions under which fish movement is hindered or blocked are unknown. Passage at diversion dams may be a function of the size of the fish, however no longitudinal distributions of small fish species were unequivocally associated with diversion dams (Duncan et al. 2010). Documenting passage of large fish species and individuals is most common because these species are suitable for attachment of radio transmitters. Movements of smaller fish species are more difficult to monitor, and non-game fish species movements are rarely monitored; therefore, very little is known regarding the passage of the majority of the 56 fish species found in the Yellowstone River, including ecologically-important forage fishes and species of concern such as Sturgeon Chub and Sicklefin Chub. The cumulative effects of all six diversion dams on the longitudinal distribution and abundance of all Yellowstone River fish species is not known with certainty.

The available information indicates that Blue Suckers regularly passed upstream at Intake and Cartersville diversion dams, but the annual movements of Shovelnose Sturgeon are largely blocked by these diversions (Jaeger et al., in review). Facilitating passage at these diversions would probably benefit Shovelnose Sturgeon populations by making habitat available upstream of Cartersville Diversion. However, the effect of altered riverine processes resulting from damming of the Bighorn River on the suitability of reaches upstream of Cartersville Diversion is not known. Sauger passed diversion dams, however it was thought that smaller Sauger may be blocked at Intake Diversion because Sauger were more abundant, but smaller below Intake Diversion Dam (Jaeger et al. 2005). There is less information on passage at diversion dams upstream of Cartersville and on passage by Burbot, Channel Catfish, and Spiny Softshells because these species had shorter home ranges which resulted in fewer encounters with diversion dams (Jaeger et al. in review).

Pallid sturgeon are a federally endangered species, that is presumably lacking successful recruitment in the Yellowstone River for decades, because the population of wild fish and adults which number less than 150 individuals (Braaten et al. 2009). Pallid sturgeon are blocked by Intake Diversion Dam in most instances, which eliminates access to potential upstream spawning sites. This is thought to preclude their recruitment because it limits the length of river available upstream of Lake Sakakawea available to drifting Pallid Sturgeon larvae (Braaten et al. 2015). Pallid sturgeon drifting downstream to the headwaters of Lake Sakakawea may encounter an anoxic zone caused by microbial respiration such as was demonstrated for the headwaters of Fort Peck Reservoir in Montana (Guy et al. 2015). There are plans to provide for passage by Pallid Sturgeon at Intake Diversion Dam. The chosen alternative is to construct a bypass channel around the weir approximately 2.1 miles long and construct a new concrete weir 40 feet upstream of the existing weir that will be 6 feet in width and span the Yellowstone River. Fill would be placed between the new weir and the existing weir to provide for a seamless transition. Fill would also be placed upstream of the new weir structure and sloped to include rock protection. The weir crest will include a low-flow channel for fish passage (USBOR and Corps of Engineers 2010; USBOR and Corps of Engineers 2012).

Summaries of the information regarding fish passage at the six mainstem diversion dams are presented below. Information on fish passage at diversion dams comes from radio telemetry studies and recaptures of tagged fish (Haddix and Estes 1976; Graham et al. 1979; Peterman 1979; Stewart 1990; Stewart 1992; White and Bramblett 1993; Bramblett 1996; Bramblett and White 2001; Jaeger et al. 2008; Jaeger et al., in review).

Intake Diversion Dam was completed in 1911 and is located at river kilometer 115 near Glendive, Montana. A side channel is present on the right side (facing downstream) of the river, and upstream fish passage using the side channel is reported to be possible at flows above 22,954 cfs (White and Bramblett 1993) to 30,000 cfs (Bureau of Reclamation 2014). Fish species have been documented passing upstream of the dam under certain flow conditions, but it is not usually known whether the fish passed over the dam itself or passed via the side channel. Paddlefish pass during years of above-average flow (Stewart 1992), at flows above 44,990 cfs (Peterman 1979), and Shovelnose Sturgeon (White and Bramblett 1993; Bramblett 1996), Walleye (Graham et al. 1979), and Sauger (Graham et al. 1979; Jaeger et al. 2005) have been observed passing Intake. However, Intake Diversion Dam probably restricts juvenile Sauger movement, because catch rates and juvenile abundance were higher below the dam than above (Jaeger et al. 2005).

Jaeger et al. (in review) analyzed radio telemetry data from 2005-2009 for Blue Sucker, Burbot, Channel Catfish, Shovelnose Sturgeon, and Spiny Softshells to determine whether animals were able to pass Intake Diversion Dam and if so, if they passed via the side channel or main channel routes. There were 69 documented events of upstream passage by radio-tagged Blue Suckers (92 percent of encounters; 90 percent of these events were using the main channel route), 2 passage events by Burbot (22 percent of encounters; 100 percent of these events were using the main channel route), 3 passage events by

Channel Catfish (75 percent of encounters; 67 percent of these events were using the main channel route), 3 passage events by Shovelnose Sturgeon (16% of encounters; 100 percent of these events were using the main channel route), and 2 passage events by Spiny Softshells (100 percent of encounters; 100 percent of these events were using the side channel route).

Helfrich et al. (1999) evaluated passage at Intake Diversion Dam and documented low numbers of marked fish (Goldeye, Sauger, Walleye, Smallmouth Buffalo) passing upstream of the dam and no consistent size differences in fish below and above dam. However, Shovelnose sturgeon were more abundant below dam, and more species were captured below dam.

No radio-tagged Pallid Sturgeon passed upstream of the dam during 1992-1994 (Bramblett and White 2001), however five adult radio-tagged Pallid Sturgeon (four males and one gravid female) passed the dam by using the side channel between 27 May and 4 June, 2014. Discharge during the passage period ranged from 46,900 to 63,800 cfs. The female Pallid Sturgeon is thought to have subsequently spawned in the Powder River (Mike Backes, 2015, MFWP, unpublished data).

Cartersville Diversion Dam was completed in 1934 and is located at river kilometer 379 at Forsyth, Montana. No side channel bypasses the diversion dam. It has long been thought to be a barrier to Shovelnose Sturgeon because they were present below, but not above Cartersville (Haddix and Estes 1976; Stewart 1990). Although Helfrich et al. (1999) captured three Shovelnose Sturgeon above the dam in 1997, Cartersville Diversion appears to be a complete barrier to the upstream distribution of Shovelnose Sturgeon because they were historically present upstream to, and in the Bighorn River (Simon 1951). As such, Cartersville Diversion Dam has a major impact on Shovelnose Sturgeon distribution, although altered ecological conditions caused by Yellowtail Dam also may reduce the suitability of the Yellowstone River below the Bighorn River. Sauger have been documented passing Cartersville Diversion Dam (Graham et al. 1979; Jaeger et al. 2005).

During 2005-2009, there were 17 documented events of passage by radio-tagged Blue Sucker (94 percent of encounters), 6 by Burbot (43 percent of encounters), 1 by Channel Catfish (25 percent of encounters), 0 by Shovelnose Sturgeon (100 percent of 15 encounters), and 1 by a Spiny Softshell (20 percent of encounters) (Jaeger et al., in review). Recapture of a floy-tagged Sauger and a floy-tagged Channel Catfish indicated that they had passed Cartersville Diversion Dam (M. Ruggles, MFWP, personal communication). Helfrich et al. (1999) found no consistent size differences in fish of multiple species below and above the dam.

Yellowstone Diversion Dam (also known as Meyers Diversion Dam) was completed in 1909 and is located at river kilometer 447 near Hysham, Montana. No side channel bypasses the diversion dam. Telemetered Sauger were documented passing upstream of this diversion dam (Jaeger et al. 2005) and there were two documented events of passage by Channel Catfish (67 percent of encounters) during 2005-2009 (Jaeger et al., in review). Recapture of a floy-tagged Sauger and a floy-tagged Channel Catfish indicated that they had passed Yellowstone Diversion Dam (M. Ruggles, MFWP, personal communication).

Rancher’s Ditch Diversion Dam was completed in 1904 and is located at river kilometer 470, which is about 4 river kilometers below the confluence of the Bighorn River. A side channel bypasses the diversion dam, but the side channel also has a diversion dam. Telemetered Sauger were documented passing upstream of this diversion dam (Jaeger et al. 2005) and passage by one Channel Catfish was documented (100 percent of encounters) during 2005-2009 (Jaeger et al., in review). Recapture of a floy-tagged Sauger and a floy-tagged Channel Catfish indicated that they had passed Ranchers Ditch Diversion Dam (M. Ruggles, MFWP, personal communication). However, Ranchers Ditch Diversion Dam has been modified to increase elevation subsequent to these documented passage events, therefore it is not known if any fish passage occurs currently (Mike Backes, MFWP, personal communication).

Waco (also known as Custer) Diversion Dam was completed in 1907 and is located at river kilometer 509. A side channel bypasses the diversion dam. Telemetered Sauger were documented passing upstream of this diversion dam (Jaeger et al. 2005), and one Burbot (33 percent of encounters) and one Channel Catfish (100 percent of encounters) passed it during 2005-2009 (Jaeger et al., in review). Recapture of a floy-tagged Sauger and a floy-tagged Channel Catfish indicated that they had passed Waco Diversion Dam (M. Ruggles, 2015, personal communication).

Huntley Diversion Dam was completed in 1934 and is located at river kilometer 566 at Huntley, Montana. A side channel and a small artificial channel bypass the diversion dam which was recently modified to attempt to improve fish passage (Mike Ruggles, MFWP, personal communication). No Sauger have been documented passing the dam, but this dam was probably not encountered by telemetered Sauger (Jaeger et al. 2005). There was one impedance event documented for Burbot (100 percent of encounters) at Huntley Diversion Dam (Jaeger et al., in review). Low numbers of marked fish (White Sucker, Common Carp, Goldeye, Brown Trout, Shorthead Redhorse, Longnose Sucker, and Flathead Chub) were documented to have passed the dam, and no consistent size differences existed in fish below and above dam (Helfrich et al. 1999). Sauger historically used the lower Clarks Fork of the Yellowstone but very few Sauger are found above Huntley Diversion at present (Mike Ruggles, 2015, MFWP, personal communication).

4.9.4.8 Tributary Connectivity

Humans have altered the connectivity between the mainstem Yellowstone River and its tributaries in a number of ways including by altering tributary hydrology through dams, water spreader dikes, irrigation withdrawals, as well as by installing impassable fish barriers such as diversion structures and culverts. Connectivity between mainstem rivers and tributaries is important because many fish species use both habitats at some point in their life histories. Connectivity between mainstem rivers and tributaries also supports higher fish species richness in both the mainstem river and the tributary (Schaefer and Kerfoot 2004), and headwater streams that are distant from mainstem rivers typically have fewer fish species than similarly-sized streams that are directly connected to mainstem rivers (Osborne and Wiley 1992; Schaefer and Kerfoot 2004; Hitt and Angermeier 2008; Mullen et al. 2011).

Connectivity between the lower Yellowstone River and its tributaries is crucial for Western Silvery Minnows, Flathead Chubs, and Sand Shiners (Duncan et al. 2010). Nearly three-quarters of Western Silvery Minnows, Flathead Chubs, and half of Sand Shiners used both mainstem and tributary habitats during their lifetimes (Duncan et al. 2010). These three species were three of the four most abundant small fish species in the Yellowstone River below the Tongue River (only Emerald Shiner were more abundant in this reach of the Yellowstone River). As such, they are almost certainly important food items for game fish species such as Sauger and Channel Catfish, for the endangered Pallid Sturgeon, as well as for other predators such as fish-eating birds. Forage fish such as these three minnow species make up much of the primary and secondary consumer biomass in the Yellowstone River’s food web and therefore are critical components of energy flow in a functioning ecosystem. All three species are roughly equally abundant, but Flathead Chub and Western Silvery Minnow have a larger body size than Sand Shiners, so they probably provide more energy to higher trophic levels. The magnitude of dispersal between the mainstem and tributaries increased with tributary basin area (Duncan et al. 2012). Therefore, the larger the tributary, the more energy flow between the tributary and mainstem. Western Silvery Minnows and Flathead Chubs have experienced range reductions and population declines elsewhere (Pflieger and Grace 1987; Hesse et al. 1989; Harland and Berry 2004; Haslouer et al. 2005), therefore maintaining tributary connectivity in the Yellowstone is important to preserve these species in this area. Of the three minnow species studied by Duncan et al. (2012), Flathead Chubs are probably most important as forage for the endangered pallid sturgeon because they are the most benthic-oriented of the three species and Pallid Sturgeon are primarily benthic predators. In the Missouri River above Fort Peck Reservoir, juvenile (age-6 and age-7) Pallid Sturgeon primarily consumed fish (90 percent by wet weight), and Sturgeon Chub and Sicklefin Chub made up 79% of the number of identifiable fish in juvenile Pallid Sturgeon stomachs (Gerrity et al. 2006). In the Yellowstone River, Sturgeon Chub range upstream as far as the Tongue River, and Sicklefin Chub are found primarily below Intake (Duncan et al. 2012). Therefore, Pallid Sturgeon diet probably varies longitudinally on the Yellowstone River.

Reestablishing connectivity on tributary streams can result in changes to tributary fish communities (Shilz 2012; Mike Backes, Montana Fish, Wildlife & Parks, unpublished data). In 2011, a canal crossing at the mouth of Pryor Creek that blocked fish movements from the Yellowstone River was replaced with a siphon that allowed for fish passage into Pryor Creek. Fish abundance increased 45 percent, Flathead Chub abundance increased 58 percent, and Index of Biotic Integrity (Jaeger et al. 2005) scores increased 34 percent the reach above the former barrier the year after barrier removal (Schilz 2014). On the Tongue River, the Muggli bypass was installed in 2008 to allow fish to bypass the T&Y Diversion Dam, which was thought to have blocked passage of all fish attempting to ascend the Tongue River. Since 2008 the Muggli bypass has allowed passage of 28 fish species, including five species (Goldeye, Freshwater Drum, Sturgeon Chub, Bigmouth Buffalo and Smallmouth Buffalo) that were not documented upstream of T&Y Dam prior to bypass construction. The Muggli bypass allows multiple Yellowstone River fish species to ascend an additional 169 miles of the Tongue River that prior to 2008 were restricted to 20 river miles (Mike Backes, Montana Fish, Wildlife & Parks, unpublished data). Fish passage projects have also been completed and have showed successful fish passage at the S & H Diversion on the Tongue River and on the Clear Creek, a Powder River tributary in Wyoming.

Mainstem-tributary connectivity is important for spawning Yellowstone Cutthroat Trout. Dewatering of spawning tributaries caused by irrigation withdrawals appeared to limit the recruitment of Yellowstone Cutthroat Trout in the Yellowstone River (Clancy 1988). Tributaries are heavily used by Yellowstone Cutthroat Trout for spawning; most (75 percent) radio-tagged Yellowstone Cutthroat Trout spawned in tributaries, followed by side channels (23 percent), and the main channel (2 percent; DeRito et al. 2010).

4.9.4.9 Altered Water Quality

The water chemistry of the Yellowstone River varies longitudinally (Appendix 5 (Water Quality)). Most water quality parameters such as hydrogen ion concentration (pH), total dissolved solids, conductivity, nutrients, water temperature, sediment, and turbidity increase in a downstream direction, only dissolved oxygen (DO) decreases downstream. For the most part, these longitudinal gradients are natural and native fish species have evolved adaptations to exist in the water quality setting of their preferred longitudinal location.

Human-caused changes to the water quality of the Yellowstone River are generally moderate, and beneficial uses are fully or partially supported, including supporting fish populations. Some water quality parameters have decreased due to improved treatment of industrial and municipal waste discharges. Because limited water temperature data exist, changes in water temperatures cannot be determined statistically although a slight increase in recent years is noted.

Sediment and associated turbidity, which are natural and important components in the warmwater fish zone have declined due to dams and impoundments on the Bighorn and Tongue rivers, which capture sediment and virtually halt sediment delivery below the dams. Annual sediment delivery at the mouth of the Bighorn River has declined from an estimated at 7.2 million tons to 1.5 million tons per year, which represents an 80% decline (Silverman and Tomlinson, 1984). These two dams have also reduced the ecological suitability of the Bighorn and Tongue rivers as well as the Yellowstone River below the confluence of the two tributaries for turbid water fishes. Fish species adapted to high turbidity including Shovelnose Sturgeon, Flathead Chub, Goldeye, Plains Minnow, Western Silvery Minnow, and Sturgeon Chub have been disappearing from Wyoming rivers that are heavily modified by reservoir construction. Goldeye, Plains Minnow, Western Silvery Minnow, and Sturgeon Chub formerly occupied the Bighorn River, but are now apparently extirpated there, presumably due to dam-related altered ecological conditions (Quist et al. 2004; Wyoming State Wildlife Action Plan 2010). Moreover, Sturgeon Chub populations in the Yellowstone River almost certainly formerly extended upstream to the mouth of and into the Bighorn River, however no Sturgeon Chub were captured above the Tongue River during extensive sampling (Duncan et al. 2012; Reinhold et al. 2014). Sauger have also declined in the Yellowstone River in the vicinity of and below the confluence of the Bighorn River, probably due to reduced temperatures, reduced sediment yield and associated turbidity, dampened spring peak flows that cued upstream migration, diversion dams, and habitat changes (McMahon and Gardner 2001). Although the confluence of the Bighorn River remains as the approximate boundary between the transition fish zone and the warmwater fish zone (White and Bramblett 1993), this demarcation is probably less definite now because the suitability of reaches below the Bighorn River for turbid water fish species has declined since installation of Yellowtail Dam. The Clarks Fork lacks large dams but no longer has runs of Sauger and there is also a suspected decline in Burbot. Water quality, quantity, and diversions are thought to be responsible (Mike Ruggles, 2015, MFWP, personal communication).

Human-caused increases in nutrients can cause eutrophication and increase algal biomass or change the composition of algal communities. In the Yellowstone River, algal biomass and algal nutrient indicator species were highest in the middle reaches of the river from Billings to Forsyth and was associated with inflows from the Clarks Fork and Bighorn rivers. Tolerant invertebrate taxa were more abundant in the middle reaches of the river (indicating slight impairment), and particularly below the confluences of the Clarks Fork and Bighorn rivers. Although the effects of these observed algal and invertebrate community metrics on the Yellowstone River fish community are not known, excessive changes in algal and invertebrate communities could affect fish food (invertebrate) production and ultimately fish populations.

Mercury has been detected in fish tissues and Montana Fish, Wildlife & Parks has issued mercury-related fish consumption advisories for multiple species in Tongue River Reservoir, Bighorn Lake, and Cooney Reservoir, and for Channel Catfish in the Yellowstone River near the Powder River (Appendix 5 (Water Quality)). Pesticides were detected in 54 percent of water samples at Billings and 95 percent of samples at Sidney, although these samples were in the lowest 25 percent of concentrations measured across the United States (Appendix 5 (Water Quality)). There have been no studies to determine if these contaminants have had lethal or sublethal effects on Yellowstone River fish.

A total of 39 pipelines transporting raw crude oil, petroleum products, liquefied natural gas, and natural gas intersect the Yellowstone River between Gardiner and the confluence with the Missouri River. On July 1, 2011 the ExxonMobil Silvertip pipeline ruptured and a reported sixty-three thousand gallons of crude oil were spilled into the Yellowstone River near Laurel, Montana at near peak discharge. The 2014 Montana 303(d) lists CEA reaches A18 to B4 (downstream from the pipeline) as not supporting aquatic life and contact recreation uses due to the spill. A report on the effects of the spill on the fish community is not yet publicly available due to an ongoing lawsuit between the State of Montana and ExxonMobil.

On January 17, 2015 the Poplar Pipeline carrying Bakken crude oil across the Yellowstone River near Glendive, Montana was breached and an estimated 12,000 gallons to 50,000 gallons was released under the ice of the frozen river. Water samples from the Glendive water supply were found to contain benzene, and residents were put on alert to not use the water for culinary purposes. Oil sheen was observed on the river almost to Sidney. Although effects of this spill on the fish community are not known, this lower reach of the river provides habitat for the endangered pallid sturgeon, and the following species of concern: Paddlefish, Shortnose Gar, Sturgeon Chub, Sicklefin Chub, Blue Sucker, Burbot, Sauger, Spiny Softshell, and Snapping Turtle. Montana Fish, Wildlife & Parks has issued a fish consumption advisory for the Yellowstone River from the spill site downstream to the North Dakota border (MFWP 2015a). Oil spills during winter under the ice present obvious logistical difficulties with cleanup efforts and may lead to more dispersion of oil and a longer exposure time to aquatic life.

4.9.4.10 Fish Entrainment in Water Withdrawal Structures

A physical inventory of pumps, irrigation canals and diversion structures on the Yellowstone River and 7 major tributaries indicated that 340 structures were on the Yellowstone River; only 16 percent of the 687 irrigation withdrawal structures were screened. However, most screening of pumps and headgates is to prevent clogging with debris, and the efficacy of screens at preventing entrainment of fish at most withdrawal sites is not known. Therefore, fish entrainment is probably a considerable source of mortality for Yellowstone River fishes. For example, prior to screening, fish entrainment at the Intake Diversion Canal included 25 native fish species and involved an estimated 382,609 to 809,820 individual fish during an annual irrigation season (Hiebert et al. 2000). Moreover, elimination of entrainment at all diversion dams would reduce adult Sauger mortality by an estimated 24-30 percent, and reduce juvenile Sauger mortality even more because juveniles experience higher entrainment rates than adults (Jaeger et al. 2005).

The T&Y Canal diverts irrigation water from the Tongue River 20 miles upstream of the Yellowstone River. The Intake headworks structure was screened to reduce fish entrainment into the canal in 1998-1999. In 1997, prior to screening an estimated 37,000 individual fish representing 22 species were entrained into the T&Y Canal during the irrigation season (Bollman 2013). Screening was moderately effective, as monitoring in 2004, 2005, and 2013 indicated that about 8,000 to 30,000 fish were returned to the Tongue River via the screened bypass during the years monitored. However, an estimated 22,000-27,000 individual fish were still entrained into the T&Y Canal annually (Bollman 2013).

4.9.4.11 Introduced Species

Although introduced species are present, overall the Yellowstone River remains a stronghold of native fish diversity, with the highest number of native fish species in Montana. There are 59 fish species total, of which 22 species (37 percent) are nonnative. However, in terms of abundance, most nonnative fish are rare. The abundances of native species is high and the proportion of nonnative species is low relative to other large rivers such as the Missouri River (Duncan et al. 2013; Reinhold et al. 2014; R. Wilson, USFWS, unpublished data; T. Haddix, MFWP, unpublished data), indicating that the lower Yellowstone River maintains productive and diverse native fish communities. Exceptions are in the coldwater or salmonid zone of the river (White and Bramblett 1993), where Rainbow Trout and Brown Trout are more numerous than the native Yellowstone Cutthroat Trout. Rainbow Trout and Brown Trout compose larger percentages of the trout population proceeding downstream in the coldwater zone and compose about 71% of the trout population at Corwin Springs, Montana, 89 percent at Mill Creek, and 88-100 percent of the trout population at Springdale, Montana. Moreover, Yellowstone Cutthroat Trout are apparently declining in abundance in the Springdale section of the Yellowstone River where they have declined from about 6-12 percent of the electrofishing catch in 2003 and 2004 to <1% in 2005, 2008, and 2009 (Scott Opitz, MFWP, unpublished data).

Rainbow Trout hybridize with native Yellowstone Cutthroat Trout, but hybridization is reduced because Rainbow Trout and Rainbow x Yellowstone Cutthroat Trout hybrids spawn earlier than Yellowstone Cutthroat Trout (DeRito et al. 2010). Brown trout are predaceous, and consume native fishes, but the effect of the presence of Brown Trout on the native fish populations has not been quantified. Lake Trout were illegally introduced into Yellowstone Lake in Yellowstone National Park in the 1980s (Munro et al. 2005) where they preyed on Yellowstone Cutthroat Trout, causing severe declines in their abundance in the lake and in spawning tributaries. Suppression efforts using primarily gill nets have removed nearly 450,000 Lake Trout from Yellowstone Lake from 1995 through 2009 (Syslo et al. 2011).

In the lower Yellowstone River Basin, stocking of introduced game fish species into or below reservoirs such as the Tongue River Reservoir, Bighorn Lake, and Lake Sakakawea, has provided a source of introduced species to the Yellowstone River. Smallmouth Bass are now established in the Yellowstone River from above the mouth of the Powder River to Billings (White and Bramblett 1993; Montana Fish, Wildlife & Parks 2015). Smallmouth Bass are potentially competing with Sauger, because their diet overlaps almost completely as indicated by stable isotopic tissue analysis (Rhoten 2011). Walleye isotopic signatures did not overlap those of Sauger (Rhoten 2011), however both Sauger and Walleye are upper trophic level piscivores, so competition for food is possible. Walleye can hybridize with native Sauger but hybridization does not appear to be an immediate threat because hybridization rates in spawning aggregations in the Yellowstone River were less than 3 percent (Bingham et al. 2011). Other nonnative fish species with potential to influence native fish communities include Common Carp, Northern Pike, Yellow Bullhead, White Bass, Rock Bass, Bluegill, Pumpkinseed, and Green Sunfish. These nonnative fishes prey on and may compete with native fishes, but their effect on the ecosystem has not been quantified. Because the introduced species did not evolve in mountain snowmelt hydrological settings, human changes to the natural Yellowstone River hydrograph may favor these introduced species.

American bullfrogs (*Lithobates catesbeianus*) have been introduced into the floodplain of the Yellowstone River (Sepulveda et al. 2014). Bullfrogs were first reported from a pond near Billings in 1999, and as of 2013 are rapidly spreading and are known to occupy about 66 miles of Yellowstone River floodplain (Sepulveda et al. 2014). Bullfrogs are generalist predators, and have been implicated in declines of native amphibians and reptiles worldwide (Ficetola et al. 2007). Native amphibians that may be affected include Northern leopard frog (*Lithobates pipiens*), Woodhouse’s toad (*Anaxyrus woodhousii*), and Great Plains toad (*A*. *cognatus*) (Sepulveda et al. 2014). Introduced red-ear slider turtles (*Trachemys scripta elegans*) have also been reported in the Yellowstone River (Mike Ruggles, MFWP, personal communication).

4.9.4.12 Recreational Fishing

Recreational fishing in the Yellowstone River is a major source of recreation and income for Montana, Wyoming, and Yellowstone National Park. The upper river is a world-famous trout fishery with anglers targeting Rainbow, Brown and Yellowstone Cutthroat Trout (Figure 4-153) as well as Mountain Whitefish. In Montana, Yellowstone River fishing pressure is highest in the reaches below Yellowstone National Park downstream to the confluence of the Boulder River, where an estimated 80,751 angler days occurred from March 2011 to February 2012 (MFWP 2011). Fishing pressure was moderate during this period in the reach from the Boulder River downstream to the mouth of the Bighorn River and was estimated at 47,678 angler days. As the fish community changes from upstream to downstream, so do the fish species targeted by anglers. Near Billings, and proceeding downstream to the mouth of the Bighorn River, anglers fish for Brown Trout and cool-water and warmwater species such as Burbot, Channel Catfish, Smallmouth Bass, Sauger, and Walleye.

Figure 4-153 Yellowstone Cutthroat Trout

Fishing pressure in the lower Yellowstone River from the Bighorn River confluence downstream to North Dakota was estimated at 35,469 angler days in the 2011 Statewide Angler Pressure Estimates (Caleb Bollman, MFWP, personal communication). The reach of the Yellowstone River in Prairie, Dawson, and Richland counties had most angler days in Montana Fish, Wildlife & Parks (MFWP) Region 7, and angling on the Treasure, Rosebud, and Custer counties reach of the Yellowstone River was third-highest. Angling from the Bighorn River confluence to Miles City is generally focused toward Sauger, Walleye, Smallmouth Bass, and Channel Catfish. Smallmouth Bass and Channel Catfish are the most abundant sport fish sampled in this reach in annual MFWP electrofishing surveys. The influence of Yellowtail Dam reducing turbidity from suspended sediments has made this reach more suitable for smallmouth bass than the Lower Yellowstone below the Powder River confluence. The same geology that confines the Yellowstone River's geomorphology through part of Custer County and Prairie County makes this reach popular with channel catfish anglers targeting these fish in and around large boulders and bedrock features. Annual MFWP surveys and tag returns demonstrate the availability of Sauger in this reach as well. Jaeger et al. (2005) estimated annual angling mortality of Sauger was relatively low at 18.6 percent. Past data collection suggests the reach below the Powder River Confluence downstream to Fallon is one of the more consistent locations used by Sauger during spawning. While there is some angling for Shovelnose Sturgeon upstream as far as Carterville Diversion Dam, angling for this species is more common and abundances are greater downstream of the Powder River confluence. Sauger, Walleye, and Channel Catfish continue to be abundant and popular sport fish in Dawson and Richland counties with the additional opportunity of a recreational snag fishery for Paddlefish during spring spawning runs, with most of the angling and harvest downstream of Intake Diversion Dam. Fishing contests on the Lower Yellowstone River are increasing in popularity with two newly proposed contests for 2015, a Walleye and Smallmouth Bass tournament at Miles City, and a Walleye, Sauger, and Northern Pike tournament at Savage. These are in addition to two long-standing catfish tournaments based out of Sidney (Caleb Bollman, MFWP, personal communication).

4.10 Biology: Terrestrial Animals (Avian)

4.10.1 Introduction

This section describes the potential impacts of human activities within the Yellowstone River corridor on riparian bird communities. For terrestrial animals such as riparian birds, land use management along rivers usually impacts species indirectly through changes to habitat resources. Consequently, discussion about how various land uses impact avian communities will focus on the alteration of habitat condition.

Impacts to habitat resources are generally reflected in two ways, either through changes to the availability of suitable habitat, or through changes to the quality of habitat that is available. Habitat availability is altered through changes in the extent, composition, and configuration of habitat that provides necessary resources to avian communities. Habitat quality is altered when existing habitat is degraded through changes to biological interactions, such as changes in rates of nest parasitism. This section focuses on the most important changes to habitat availability and quality due to human influences along the Yellowstone River. These changes to riparian habitat condition include:

- Decline in extent of cottonwood forest habitat;
- Alteration of riparian grasslands;
- Loss of structurally complex forest habitat;
- Loss of landscape-level habitat heterogeneity
- Degradation of cottonwood habitat due to the expansion of Brown-headed Cowbirds;
- Degradation of habitat due to the spread of invasive plant species.

This section focuses mostly on the influences of land use on habitat condition for terrestrial birds, particularly riparian species. However, human influences potentially have a strong negative impact on aquatic and in-channel habitat resources that are crucial to the Least Tern, a federally listed endangered species that deserves special consideration. Consequently, changes to habitat resources that are relevant to this species will also be discussed, including:

- Loss and degradation of in-channel nesting and foraging habitat

Important relationships between riparian birds and habitat resources were previously identified for the Yellowstone River (Jones 2014). Changes to habitat condition impact avian communities in various ways. Impacts to avian communities will be discussed in terms of ‘avian responses’, which are aspects of the avian community that are expected to change as a result of alterations to habitat resources. Avian responses impacted by changes in habitat condition along the Yellowstone River are summarized in the following section. Implications of changes in habitat condition for avian responses will then be summarized for each habitat condition.

Appendix 9 (Avian) contains a summary of supporting documents, as well as complete results of analyses performed in support of the discussions included herein. Please refer to that document for a more thorough discussion of the covered topics, and for complete citations of referenced documents.

4.10.2 Summary of Avian Responses

Riparian bird communities were documented during three field studies conducted between 2001 and 2009 (primary data sources described in Appendix 9; Jones and Hansen 2009; Hansen et al. 2003). More than 80 avian species were observed in riparian habitats in the study area; sixty-seven species were detected along the Lower Yellowstone River (downstream from Springdale, Montana), and 15 additional species were detected along the Upper Yellowstone River. See Appendix 9 (Avian) for a complete list of observed species, with scientific names. Cottonwood forest was the focus of most of the avian sampling efforts along the river because it is the most extensive habitat in the riparian zone, and avian abundance and diversity are highest in cottonwood forest compared with other riparian habitat types. Consequently, methods and results discussed herein emphasize this habitat type. However, other habitat types (e.g., riparian grasslands, aquatic habitats) will be discussed when relevant.

Avian responses are specific aspects of the avian community that are expected to change as a result of changes in habitat resources. The following guilds (i.e., groups of species that share similar traits) and species will be included as avian responses in discussions about implications for status and trends in riparian habitat condition. See Jones (2014) and Appendix 9 (Avian) for further discussion about evidence for relationships between these avian responses and habitat condition along the Yellowstone River.

Bird species richness: The number of different species observed at a site, usually within one particular habitat type, at a given time.

Individual species of special conservation concern: Species of Concern (SOC) and Potential Species of Concern (PSOC) in Montana (based on designation by the Montana Natural Heritage Program and Montana Fish, Wildlife & Parks (2013)); these are focal species because they may be especially vulnerable to changes in habitat condition. These include:

- PSOC: Black-and-white Warbler, Chimney Swift, Dickcissel, Ovenbird, Plumbeous Vireo
- SOC: Black-billed Cuckoo, Bobolink, Red-headed Woodpecker, Veery, Least Tern

Conservation species: Species that are experiencing population declines. Twenty-six riparian bird species observed along the Yellowstone River are conservation species (including the PSOC and SOC).

Forest specialist species: Species that prefer habitats comprised of extensive forest; these species generally are not found in areas with only small amounts of forest cover. Eighteen riparian bird species observed along the Yellowstone River are forest specialist species. Seven are conservation species, including:

- PSOC: Black-and-white Warbler, Ovenbird, Plumbeous Vireo
- SOC: Black-billed Cuckoo, Veery

Understory specialist species: Species that prefer structurally complex riparian forest with a dense understory. Thirteen riparian bird species observed along the Yellowstone River are understory specialist species. Four are conservation species, including:

- SOC: Black-billed Cuckoo, Veery

Cavity-nesting species: Species that use large live and standing dead trees for nesting and foraging. Fourteen riparian bird species observed along the Yellowstone River are cavity-nesting species. Five are conservation species, including:

- PSOC: Chimney Swift
- SOC: Red-headed Woodpecker

Grassland species: Species that depend upon riparian meadows and grasslands for nesting and foraging. Nine riparian bird species observed along the Yellowstone River are grassland species. Five are conservation species, including:

- PSOC: Dickcissel
- SOC: Bobolink

Brown-headed Cowbird host species: Species that are known to experience Cowbird parasitism of nests. Twenty-seven riparian bird species observed along the Yellowstone River are Cowbird hosts. Eleven are conservation species, including:

- PSOC: Black-and-white Warbler, Ovenbird, Plumbeous Vireo
- SOC: Veery

Bird diversity within the riparian landscape: The number of species observed collectively within the riparian landscape, across all habitat types. Diversity at this larger landscape scale is relevant when considering impacts to reaches, regions, or the entire river system.

Relevance to Non-Avian Species. Non-avian terrestrial species are also often grouped into guilds of species that share general habitat requirements. The guilds chosen here as indicators of habitat condition for avian communities are relevant to many other terrestrial riparian taxa as well. Examples of non-avian species or groups potentially impacted by changes in habitat condition will be discussed in the sections below when relevant.

4.10.3 Status and Trends in Habitat Condition and Relevance to Avian Responses

This section summarizes important characteristics of riparian habitat for birds along the Yellowstone River. Relationships between avian responses and habitat condition are thoroughly discussed in Jones (2014) and in Appendix 9 (Avian), and inferences about potential implications of habitat condition are based on these relationships. Summaries included in this section draw upon results from analyses presented in Appendix 9 (Avian), as well as results from other sections of this chapter and associated appendices. For each focal habitat condition, discussion will include summaries of:

- The status and distribution of metrics representing habitat condition
- Change in metrics of habitat condition through time
- Relevant trends in avian responses.

Table 4-21 describes the human influences on habitat condition for riparian birds along the Yellowstone River. Specific human influences will also be included in discussions for each habitat condition.

4.10.4 Cottonwood Forest Extent

The amount of forest habitat in the landscape has a strong effect on characteristics of riparian bird communities. Forest specialist species that occur along the Yellowstone River prefer areas with extensive forest cover, particularly areas of Closed Timber (TC) where the forest canopy is well-developed, and these species may not occur where the amount of forest cover is naturally limited or has been reduced through land use practices. Consequently, these species would likely be most impacted by changes in the extent of cottonwood forest habitat.

Table 4-21
Human Influences on Habitat Condition for Riparian Birds along the Yellowstone River

Direct Impact	Impact on Avian Habitat Condition	**Expected Avian Responses** (+) indicates positive influence, (-) indicates negative influence.
Human Influence: Land Use Change		
Conversion of riparian habitat to agriculture	Loss of cottonwood forest habitat	Forest specialists (-)
	Loss of grassland habitat	Grassland species (-)
Residential development and other agricultural infrastructure (e.g., corrals, feedlots) provide foraging habitat for Cowbirds	Increased abundance of Cowbirds in cottonwood forest and degradation of habitat due to parasitism	Brown-headed Cowbirds (+) Cowbird host species (-)
Human Influence: Altered Hydrology: Reduced Peak Flows (Yellowtail Dam and Irrigation Withdrawals)		
Decline in rates of channel migration and floodplain turnover alter cottonwood recruitment and successional processes	Short-term increase in the extent of cottonwood forest as existing younger stands mature without disturbance	Short-term: Forest specialists (+) Understory specialists (+)
	Long-term reduction in the extent of structurally complex mid-successional forest habitat due to declines in rates of cottonwood recruitment	Understory specialists (-) Species richness (-)
	Long-term reduction in the overall extent of cottonwood habitat as existing forests become decadent and die-off without replacement	Forest specialists (-)
Decline in rates of channel migration lead to reduced floodplain complexity	Decline in the creation of new gravel and sand bar nesting habitat, as well as a reduction in the frequency and intensity of flood scour that maintains vegetation free bars	Least Tern (-)
	Decline in the extent of shallow water secondary channels used for foraging	Least Tern (-)
	Loss of habitat heterogeneity due to a decline in the presence or abundance of particular successional stages	Bird diversity within the floodplain(-)
Isolation and dewatering of seasonally inundated side channels and narrowing of main channel	Short-term increase in the extent of cottonwood forest as channel margins and dried-out side channels are colonized and cottonwood forest stands mature	Short-term: Forest specialists (+) Understory specialists (+)
	Long-term reduction in the extent and structural complexity of cottonwood forest as side channels dry out and cottonwood forest stands mature without replacement	Long-term: Forest specialists (-) Understory specialists (-)
	Loss of shallow-water foraging habitat	Least Tern (-)

Direct Impact	Impact on Avian Habitat Condition	**Expected Avian Responses** (+) indicates positive influence, (-) indicates negative influence.
Human Influence: Altered Hydrology: Reduced Summer Low Flows (Yellowtail Dam and Irrigation Withdrawals)		
Lower discharge levels cause declines in the water table	Loss of forest habitat as stress on native riparian plant communities gives drought tolerant invasive species a competitive advantage	Cavity-nesting species (-) Forest specialists (-)
Dewatering of shallow water secondary channels	Loss of foraging habitat	Least Tern (-)
Human Influence: Isolation of Floodplain and Side Channels (Dikes, Levees, and Plugs)		
Isolated riparian areas are cutoff from floodplain processes that sustain and replenish vegetation	Decline in the extent of structurally complex habitat as isolated forest stands become functionally degraded and decadent	Understory specialists (-)
	Decline in the extent of forest habitat as isolated forest stands eventually die-off without subsequent regeneration	Forest specialists (-)
Side channels are isolated and dry out	Short-term increase in the extent of cottonwood forest as dried-out side channels are colonized and cottonwood forest stands mature	Short-term: Forest specialists (+) Understory specialists (+)
	Loss of shallow-water foraging habitat	Least Tern (-)
Human Influence: Channel Restriction (Bank Stabilization)		
Decline in rates of channel migration and floodplain turnover	Short-term increase in extent of cottonwood forest as existing young stands mature without disturbance	Short-term: Forest specialists (+) Understory specialists (+)
	Long-term reduction in the extent of mid-successional structurally complex forest habitat due to declines in rates of cottonwood recruitment	Understory specialists (-)
	Long-term reduction in the overall extent of cottonwood habitat as existing forests become decadent and die-off without replacement	Forest specialists (-)
Decline in rates of channel migration lead to reduced floodplain complexity	Decline in the creation of new gravel and sand bar nesting habitat, as well as a reduction in the frequency and intensity of flood scour that maintains vegetation-free bars	Least Tern (-)
	Decline in the extent of shallow water foraging habitat	Least Tern (-)
	Loss of habitat heterogeneity due to a decline in the presence or abundance of particular successional stages Bird diversity within the floodplain (-)	

Direct Impact	Impact on Avian Habitat Condition	**Expected Avian Responses** (+) indicates positive influence, (-) indicates negative influence.
Human Influence: Altered Sediment Regimes (Yellowtail Dam)		
Decline in the amount of sediment deposited within the floodplain	Decline in the creation of new gravel and sand bar nesting habitat	Least Tern (-)
Human Influence: Livestock Grazing		
Simplification of forest habitat due to grazing of understory vegetation	Loss of structurally complex forest habitats	Understory specialists (-)
Presence of livestock creates foraging habitat for Cowbirds	Increased abundance of Cowbirds in cottonwood forest and degradation of habitat due to parasitism	Brown-headed Cowbirds (+) Cowbird host species (-)
Human Influence: Spread of Invasive Plant Species		
Russian olive and saltcedar outcompete and replace structurally complex native cottonwood forest	Loss of habitat with large trees as monotypic stands of Russian olive and saltcedar replace native cottonwood forest	Cavity-nesting species (-) Forest specialists (-)

4.10.4.1 Current Distribution

Based on riparian habitat data from 2001, the amount of cottonwood forest generally increases in the downstream direction, with the lowest acreage/valley mile in reaches of Region A and the highest acreage in Region D (Figure 4-154). The top 6 reaches with the greatest amounts of TC forest were located in Region D, including reaches D11 and D16 which had substantially more forest than all other reaches, with almost 400 and 500 acres/valley mile, respectively (

Figure 4-154).

On average, in 2001 there was twice as much closed timber (TC) in reaches of Region D than in any other region (Figure 4-155). Most reaches in that region gained acreage of total forest and TC forest since 1950, reflecting the general increase in acreage of TC forest observed in Region D in recent years (see Section 4.7.3, Terrestrial Plants). Reaches A17, A18, and B3 contained substantially more forest than most other reaches in Regions A and B, suggesting that these reaches provide relatively important areas of forest cover within those regions (Figure 4-154).

When reaches are ranked by amount of forest habitat and TC forest, the top 25 percent of reaches contained more than half of all cottonwood forest and TC forest acreage within the Yellowstone River floodplain downstream from Springdale, Montana, and consequently represent relatively important areas of forest habitat. Furthermore, many of these reaches contained the greatest acreage of forest across all time periods, suggesting these areas have been consistently important through time. In general, reaches with the greatest amounts of forest cover and TC forest are anabranching reach types with less confinement (i.e., Unconfined (UA) or Partially Confined (PCA)), suggesting that these reach types are relatively important because they contain the most extensive forest habitats.

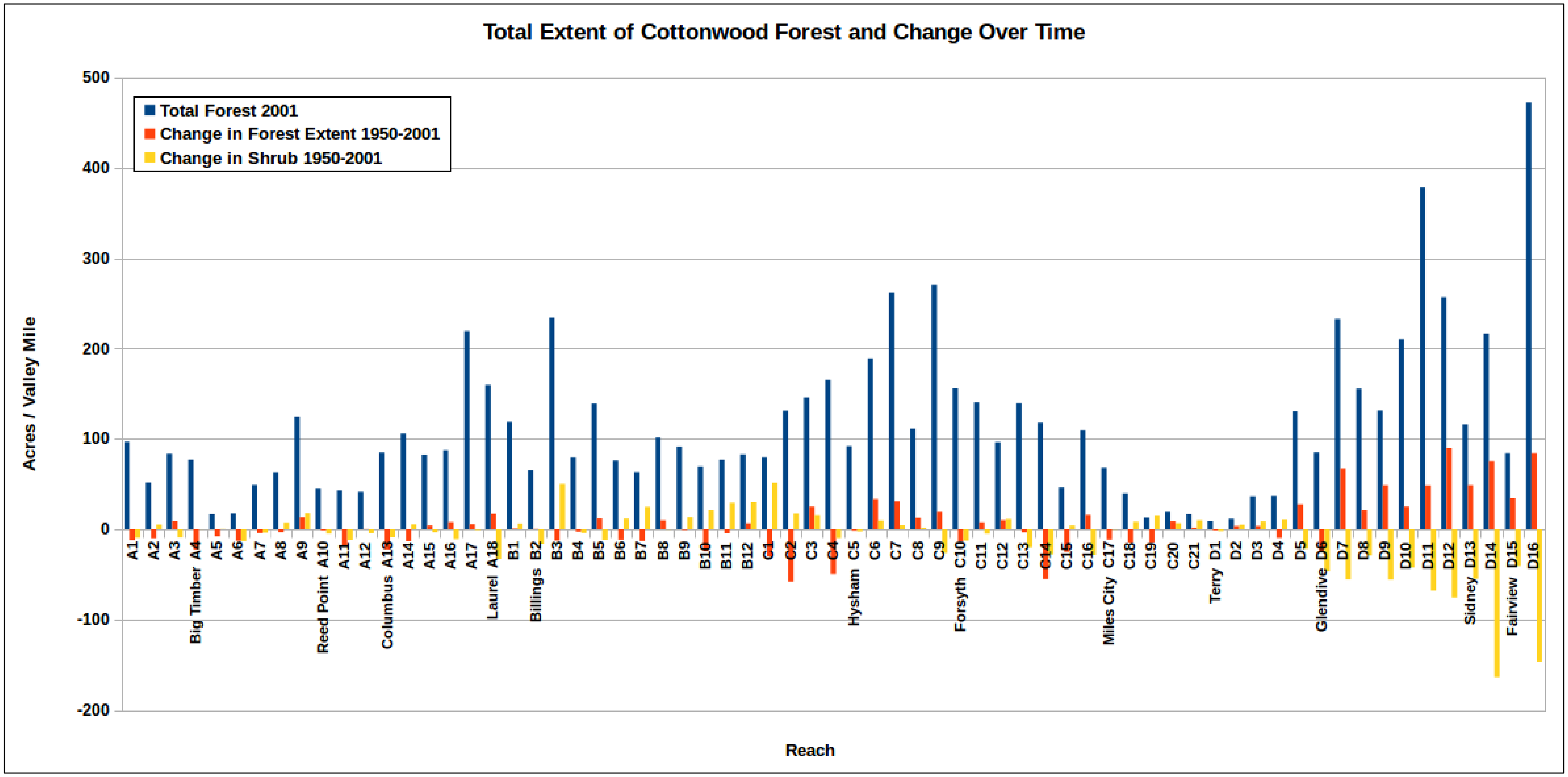


Figure 4-154 Total extent (acres/valley mile) of all cottonwood forest within reaches in 2001, as well as change in forest and shrub over time

Note: *Reaches are ordered by spatial location, upstream (A1) to downstream (D16)*

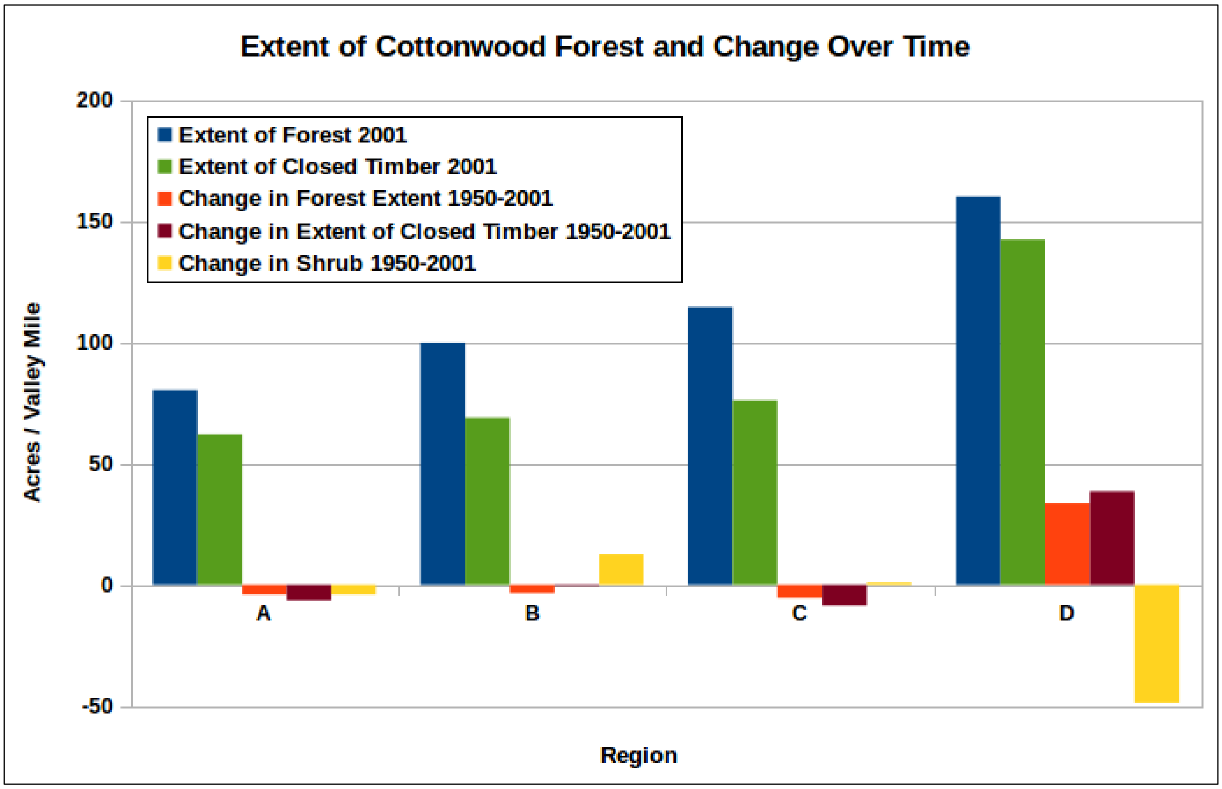


Figure 4-155 Total extent (acres/valley mile) of all cottonwood forest and Closed Timber cottonwood forest within regions in 2001, as well as change in forest and shrub over time

4.10.4.2 Change in Forest Extent

For both total cottonwood forest and TC forest, most of the top reaches were included in the top 25 percent for all three time periods, suggesting that the reaches with the greatest amounts of forest cover are consistently important through time. See Table 5-1 in Appendix 9 (Avian) for a list of reaches ranked by total amount of forest and TC forest from 1950 to 2001.

The top 25 percent of reaches with the greatest extents of forest habitat generally experienced gains in total cottonwood forest and closed timber forest acreage from 1950 to 2001. However, many of these top reaches also experienced a loss of shrub acreage during that same time period. For example, Reach D16, which gained over 80 acres of forest per valley mile, lost almost twice that much area of shrub in the same time period. These trends were especially evident in Region D where reaches gained on average approximately 30 acres of forest, most of that attributed to gains in TC forest, but lost almost 50 acres of shrub per valley mile (Figure 4-155). This indicates that the amount of forest has increased in the short term, providing more extensive cottonwood forest habitat since 1950, likely due to the transition of existing younger shrub stands to forest (see additional discussion in Section 4.7.3, Terrestrial Plants). However, the loss of shrub acreage through time suggests a decline in regeneration that could result in a long term loss of forest within these reaches that have historically provided the greatest extent of cottonwood forest, particularly the TC forest habitat type.

4.10.4.3 Human Influences on Change in Forest Extent

Likely human influences of these observed changes in characteristics of cottonwood forest communities are presented in Table 4-21 and more thoroughly discussed in other sections of this chapter. In summary, declines in shrub acreage and increases in acreage of older forest classes suggest a possible imbalance in riparian gains and losses in Regions C and D. These changes are linked to the reduced rate of floodplain turnover, which measures the exchange of area between channel and riparian vegetation, and thus represents a key process that drives cottonwood recruitment and succession. Floodplain turnover was quantified for the Yellowstone River from 1950 through 2001 (Section 4.7.3, Terrestrial Plants; Section 4.5.3.4, Geomorphology). The rate of floodplain turnover from riparian cover to channel has declined since 1950, with rates declining most steeply since 1976. The recruitment of younger TC forest along the river has also declined since 1976. River reaches in Regions A and B exhibited a more equal exchange between riparian cover classes through time, with smaller gains and losses in acres/valley mile (Figure 4-154). The total amount of habitat in these regions is much lower compared to regions downstream, and consequently small changes in acreage of shrub constitute a relatively large percent change over time for Regions A and B (on average -28 percent and 31 percent, respectively; see Figure 4-115 in Section 4.7.3). However, the smaller changes in the absolute amount of shrub (i.e., acres/valley mile) observed in reaches of Regions A and B suggest more of a balance between gains and losses compared with the consistently large, directional changes observed in most reaches of Region D.

Floodplain isolation has also likely contributed to documented changes in the extent of cottonwood forest. Floodplain isolation occurs when there is a contraction in extent of inundated areas, and reduced connectivity within the floodplain (Section 4.3, Hydraulics). An immediate increase in riparian cover occurs when isolated seasonal high water channels are no longer accessed by flood flows and can be colonized by woody vegetation. Since 1950, in Regions C and D there has been a net gain of riparian cover (greater than 55 percent; see discussion in Section 4.7.5, Terrestrial Plants) due to the recruitment and maturation of woody vegetation in abandoned high-water side channels. However, long-term declines occur when cottonwood forest in isolated side channels becomes decadent and dies off without subsequent recruitment.

Conversion of cottonwood forest to other land uses, particularly irrigated agriculture, likely occurred on a large scale before 1950 (Section 4.2.2, Land Use). Since 1950, land use conversion has altered the extent of forest habitat to a limited degree. The amount of forest converted to agriculture since 1950 was greatest in Region C (8,265 acres) and Region D (5,927 acres) (DTM 2013). Irrigated agriculture was the primary cause of land use conversion since 1950. Over 5,500 acres of 1950s woody riparian cover were converted to irrigated agricultural land uses by 2011, primarily in Regions C and D. Region D alone experienced a conversion of 2,900 acres (see discussion in Section 4.7.4, Terrestrial Plants).

4.10.4.4 Relevant Trends in Distribution of Avian Responses (Cottonwood Forests)

- Reaches that contained the largest amounts of cottonwood forest, especially Closed Timber forest, are generally located in Regions C and D. Many conservation species that are forest specialists occurred most often in these regions, including:
    - Black-and-white Warbler (PSOC)
    - Ovenbird (PSOC)
    - Black-billed Cuckoo (SOC)
- For most SOC and PSOC, greater numbers of sites were occupied in the lower reaches of the river, suggesting cottonwood forest habitat located in Regions C and D is particularly important for many species of conservation concern. The amount of forest in these regions, especially Closed Timber forest, has increased since 1950, which has likely been good for these species.

However, substantial declines in the amount of young cottonwood in those regions suggest likely long-term declines in the amount of forest that will be detrimental for these species in the future.

- Forest specialist species occurring in Regions A and B, such as Ovenbirds and Black-and-white Warblers, may particularly depend upon the few reaches in those regions that have a lot of forest (e.g., A17, A18, and B3). Although habitat data do not exist to quantify the extent of forest in reaches of Region PC, this is likely also true for Veerys and other forest specialist species occurring in that region.

4.10.5 Riparian Grassland Extent and Quality

Riparian grasslands were not the focus of avian sampling efforts because it was difficult to find enough natural grasslands to sample that were evenly distributed along the river. Most of the 30 sampled grassland sites were located in reaches A7, A11, and C7 (Jones and Hansen 2009). However, grasslands are included in discussions of important riparian habitat because many species observed along the Yellowstone River are dependent upon this habitat type, including one SOC and 4 other conservation species (e.g., over half of the 9 grassland dependent bird species observed along the river).

4.10.5.1 Human Influences on Change in Extent and Quality of Riparian Grassland

No quantitative analyses were completed to describe the status and distribution of natural riparian grasslands along the river because it is difficult to distinguish grasslands from other types of herbaceous cover (including agriculture) using aerial photographs (DTM and AGI 2008a). Riparian grassland habitat is lost when herbaceous lands are converted to agricultural crops, because grassland-dependent bird species will generally not use cropland for nesting or foraging. Furthermore, the conversion of natural herbaceous lands to irrigated hayfields often represents a degradation of habitat for birds. Although hayfields seemingly provide high-quality riparian habitat where many grassland species breed, they are usually mowed regularly during the breeding season (late May to early July), which destroys nests and often kills adult birds (see Jones (2014) for a complete review of this topic). Studies in other areas of North America have documented severe negative impacts of mowing for Savannah Sparrows, recorded at 40 percent of riparian grassland sites sampled along the Yellowstone River, and Bobolinks, a Montana SOC observed in every region downstream from Springdale, Montana. Likely human influences of changes riparian grasslands are presented in Table 4-21. More acres of herbaceous land (including grassland) have been converted to higher intensity land use since 1950 than any other riparian cover type. In each of Regions C and D, over 5,000 acres of non-irrigated herbaceous lands (which reflect lower-intensity land use including riparian grassland) were converted to irrigated agriculture (including cropland and hayfields) from 1950-2001; an additional 5,000 acres were converted in Regions A and B (DTM 2013). Most reaches in Region D experienced substantial gains in irrigated agriculture, likely due to conversions of non-irrigated herbaceous lands (Section 4.2.4.2, Land Use).

4.10.5.2 Relevant Trends in Distribution of Avian Responses (Riparian Grasslands)

- Bobolinks (SOC) and Dickcissels (PSOC) were each observed in all regions of the river except Region PC; consequently, the loss and degradation of riparian grasslands anywhere along the river may impact these species. However, the conversion of habitat was much greater in regions C and D, and may therefore impact these species more in those regions.

- Five of the grassland species observed along the river are conservation species, which are generally found in greater numbers in Regions C and D, where habitat conversion since 1950 was greatest.

- Other non-avian species are likely similarly impacted by changes in the extent and quality of riparian grassland habitat. For example, the Meadow Jumping Mouse (*Zapus hudsonius*), a PSOC in Montana, has been observed in Dawson and Richland counties (Region D) and depends upon areas of dense, lush grass in riparian grasslands and wetlands.

4.10.6 Extent of Structurally Complex Forest

The structural complexity of the forest understory has a strong effect on characteristics of riparian bird communities. Bird species richness was greater in structurally complex forests compared to more simple forest habitats along the Yellowstone River. Additionally, understory specialist species preferred cottonwood forest habitats with dense understory vegetation, and these species may not occur in forests that are more open and structurally simple.

4.10.6.1 Current Distribution of Structurally Complex Forest

The presence of large shrubs, which add significant structure to the understory of the forest stand, was the most important metric of habitat condition for understory species. However, it is not possible to quantify the status and distribution of structurally complex forest at the scale of the entire river based on attributes such as shrub density because characteristics of the forest understory cannot be observed using aerial photography.

Although not available at the scale of the entire river, habitat data collected at sites where avian communities were sampled (Jones and Hansen 2009) can provide some insight about the status and distribution of structurally complex forest habitat along the Yellowstone River. Structurally complex cottonwood forest habitat types were relatively abundant (112 of 234 cottonwood sites sampled), and were evenly distributed across regions of the river. Structurally complex forest habitats had moderate numbers of big and small cottonwood trees and high densities of large native shrubs, while more simple forest habitats were grassy in the understory or had only small shrubs.

4.10.6.2 Human Influences on Change in the Extent of Structurally Complex Forest

Likely human influences of change in the extent of structurally complex forest are presented in Table 4-21. Because no accurate metrics exist to quantify the extent of structurally complex habitat, it is not possible to assess change through time. However, change in processes that influence the extent and condition of structurally complex forests habitats may provide insight about potential trends. Structurally complex forest habitats are mid-successional forests that are created and maintained by floodplain processes that drive cottonwood succession and renewal (see Figure 4-156). Riparian turnover measures the exchange of area between channel and riparian vegetation and thus represents a driver of successional processes.

Areas with rates of riparian turnover that are out of balance (e.g., more area transitioning to forest than to channel) may experience changes in characteristics of riparian forest, with less young complex forest and more forest that is decadent and simplified in structure . Turnover was quantified for the Yellowstone River from 1950 through 2001 (see Figure 4-122 and Figure 4-123 in Section 4.7.5, Terrestrial Plants). The rate of exchange from channel to riparian cover has increased in Regions C and D since 1950; suggesting a decline in floodplain turnover in those regions (see also Section 4.5.3.4, Geomorphology for further discussion). River reaches in Regions A and B exhibited a more equal exchange between channel and riparian cover through time, suggesting more of a balance between gains and losses in those regions. These changes indicate that the availability of structurally complex forest habitat for riparian birds may decline if floodplain turnover rates continue to decline in the future, reducing the recruitment of young cottonwood forest.

Figure 4-156 Example of structurally complex cottonwood forest habitat with high bird species richness and richness of understory species

Floodplain isolation also likely contributes to documented changes in the extent of cottonwood forest. Floodplain isolation occurs when there is a contraction in extent of inundated areas, and reduced connectivity within the floodplain (Section 4.4, Hydraulics). An immediate increase in riparian cover occurs when isolated seasonal high water channels are no longer accessed by flood flows and are colonized by woody vegetation. Since 1950, in Regions C and D there has been a net gain of riparian cover (greater than 55 percent) due to the recruitment and maturation of woody vegetation in abandoned high-water side channels. Much of that forest is now (i.e., in 2001, the latest time period for habitat data) reaching mid-successional ages, suggesting that the extent of structurally complex forest, particularly in Region D where increases in acreage of closed timber (TC) are observed, may have increased since 1950. However, long-term declines will likely occur when cottonwood forest in isolated side channels ages and dies off without subsequent recruitment of younger, more complex forest. Although the acreage of TC forest has increased since 1950, recruitment has declined since 1976 (see Section 4.5.3.4, Geomorphology).

Heavy grazing potentially reduces the structural complexity in cottonwood forest when livestock graze the understory vegetation (see Section 4.7.9, Terrestrial Plants). See Jones (2014) for a complete discussion of the potential impacts of livestock grazing on riparian bird communities in the western U.S. However, no data exist to measure the intensity or impact of grazing along the Yellowstone River, so it is difficult to infer the scale of potential negative impacts for riparian birds along the river.

4.10.6.3 Relevant Trends in Distribution of Avian Responses (Structurally Complex Forests)

- The richness of conservation species increased steadily downstream, and was greatest in reaches of Region D, suggesting that a decline in species richness due to the loss of structurally complex habitats in that region may be especially detrimental for conservation species.

- The loss of structurally complex habitat in particular regions along the river may particularly impact certain understory specialist species:

- Black-billed cuckoos (SOC) were observed in regions B, C, and D; the loss of structurally complex habitat in those regions may be especially detrimental for this species.

- Veerys (SOC) were observed only in region PC, and would likely be impacted by a loss of structurally complex habitat in that region.

4.10.7 Habitat Heterogeneity within the Riparian Landscape

The habitat heterogeneity found within the floodplain of the Yellowstone River provides a variety of resources for birds. Bird species are often associated with the habitats that provide the specific resources that they need, and bird communities often vary across different habitat types. For example, the types of bird species observed in grassland habitats are usually different than species observed using Closed Timber forest. Similarly, different bird species are found in mature forest with a well-developed canopy than are found in younger shrub habitats. Consequently, the number of bird species observed within the riparian landscape likely depends upon the extent of different habitat types found within the floodplain, and a loss of habitat heterogeneity would likely result in a decline in riparian bird diversity.

4.10.7.1 Current Distribution of Habitat Heterogeneity and Change through Time

The braided and anabranching reaches (i.e., the less confined reach types) of the Yellowstone River generally contain more riparian cover and greater complexity of patch types compared with confined reach types (Section 4.7.3, Terrestrial Plants). Results from analyses in the upper reaches of the Yellowstone River support this; braided reaches in that region exhibited greater extents of different riparian habitat types than did more confined reaches (Hansen et al. 2003).

Analyses describing changes in the extent and distribution of different riparian habitats downstream from Springdale, Montana through time are presented in Section 4.7.3, Terrestrial Plants. In summary, although the total extent of riparian habitat has remained fairly stable from 1950 to 2001, changes in the extent and distribution of specific riparian habitats have occurred. Most notably, there has been a transition to older age classes of woody riparian cover and a loss in acreage of younger habitat types in Regions C and D. Similar changes were observed in Region PC of the river upstream from Springdale. In that region, the total area of the various successional stages changed from 1948 to 1999, with substantial declines in acreage of younger habitat types and increases in older habitat types (Hansen et al. 2003). These directional changes in the extent and distribution of habitat types in the floodplain of the Yellowstone River represent a decline in habitat heterogeneity that may negatively impact bird diversity in the riparian zone.

4.10.7.2 Human Influences on Change in Habitat Heterogeneity

Likely human influences of changes to habitat heterogeneity are presented in Table 4-21. Successional processes create and sustain habitat heterogeneity in the floodplain. Riparian turnover measures the exchange of area between channel and riparian vegetation and thus represents a driver of successional processes. Areas with rates of riparian turnover that are out of balance (i.e., more area transitioning to forest than to channel) may experience directional changes in characteristics of riparian forest, and a loss in habitat heterogeneity within the floodplain. Turnover was quantified for the Yellowstone River from 1950 through 2001 (Section 4.5.3.4, Geomorphology). The rate of exchange from channel to riparian cover has increased in Regions C and D since 1950 suggesting a decline in floodplain turnover in those regions (Figure 4-122, Section 4.7.5, Terrestrial Plants), particularly in braided and anabranching reaches where floodplain heterogeneity and complexity is greatest (Figure 4-123, Section 4.7.5, Terrestrial Plants). Furthermore, the extents of gravel and sand bars and secondary channels within the floodplain have substantially declined in Regions C and D since 1950 (Figure 4-69, Section 4.5.3.2, Geomorphology). These changes indicate that floodplain complexity, and consequently habitat heterogeneity within the riparian zone, may be declining in particular regions of the river, with potentially negative impacts for riparian bird diversity.

4.10.7.3 Relevant Trends in Distribution of Avian Responses (Habitat Heterogeneity)

Bird species were distributed disproportionately across the different habitats found within the Yellowstone River corridor, indicating that different habitats provide different types of resources for birds. Therefore, the maintenance of a mosaic of different habitat types within the floodplain is crucial for sustaining overall bird diversity within the riparian landscape.

4.10.8 Degradation from Brown-Headed Cowbird Parasitism

Brown-headed Cowbirds lay their eggs in the nests of other species (i.e. are nest parasites), and have been implicated in the population declines of many native birds. They breed in cottonwood forest habitat and forage in surrounding human and livestock dominated landscapes. If necessary, Cowbirds will commute far distances (on average 1 kilometer (0.621 miles) in western landscapes; see review in Jones (2014)) daily between morning breeding habitat and afternoon foraging sites. Consequently, cottonwood habitats are often degraded by parasitism when land uses exist in the riparian corridor that provide foraging habitat for Cowbirds. More than 30 avian species observed in riparian habitats along the

Yellowstone River are Cowbird host species, including 2 SOC, 3 PSOC, and 7 additional species with declining population trends.

The main human influences driving habitat degradation due to Cowbird parasitism are land use conversions within the corridor. The degradation of riparian habitat by Cowbird parasitism demonstrates a more general phenomenon where particular land uses have landscape-level effects that extend beyond their actual footprint. Some other examples of these large-scale effects include: the introduction of exotic predators or competitors that are associated with particular land uses, but quickly inhabit surrounding natural habitat; direct mortality associated with human interactions in an increasingly human-dominated landscape; and air and water pollution that originates with particular land uses, but is dispersed into surrounding habitats. These types of negative landscape-level effects impact birds as well as other riparian wildlife. The association between land use and Cowbirds provides a good case-study of the potential impacts of landscape-level effects because the relationship is well documented, and effects on habitat degradation are fairly consistent (see Jones (2014) for a complete review of the topic). The following sections discuss two different metrics that were identified for describing the potential impacts of Cowbird parasitism in riparian habitats along the Yellowstone River. Because Cowbird distribution is directly influenced by human land use, these metrics describe the extent of land uses and changes through time that likely represent changes in Cowbird parasitism (i.e., habitat degradation) within the riparian corridor.

4.10.8.1 Extent of Land Use Providing Cowbird Habitat

Along the Yellowstone River, Cowbirds were strongly correlated with the presence of human and livestock dominated land uses, including urban and exurban residential areas, and farmsteads with outbuildings for livestock and feed. These land uses correspond with land use categories identified for the Land Use Mapping effort that encompassed the 100-year inundation area, plus a 500 meter buffer (DTM 2013), so it was possible to quantify the status and distribution of Cowbird foraging habitat along the Yellowstone River as an indicator of the potential impact of parasitism on riparian bird communities. Land use categories used for analyses included urban and exurban residential areas (referred to below as ‘Residential’), as well as areas of other agricultural infrastructure, specifically corrals, feedlots, and other areas where livestock are usually present (referred to below as ‘AgInf’).

Figure 4-157 presents the amounts of Residential Exurban and AgInf land uses in all reaches in 2011. Reaches PC8 (north of Emigrant), B1 (Billings), and C17 (Miles City) contained the greatest amounts of Residential; B1 also contained substantial acreage of AgInf and had the greatest extent of land uses that provide foraging habitat for Cowbirds of all reaches. On average, Regions PC and A had the greatest areal extent of land use providing foraging habitat for Cowbirds, and most of that acreage was attributed to Residential. Region B also contained a large extent of Residential and AgInf, but much of that acreage was concentrated in the upstream reaches of the region. Total acreage of land uses that provide foraging habitat for Cowbirds was generally lowest in reaches of Regions C and D (<200 acres in most reaches), and most of that acreage was attributed to AgInf. Reaches in Region D had, on average, the least acreage of all land uses providing Cowbird foraging habitat.

Since Cowbirds are strongly correlated with livestock, the presence of grazing areas, such as pastures and grazed forest, also provide foraging areas for Cowbirds (see Jones (2014) for a complete discussion of the relationship between grazing livestock and Cowbirds). However, no data exist to measure the timing or distribution of grazing along the Yellowstone River, so it is difficult to infer the magnitude of these potential negative impacts.

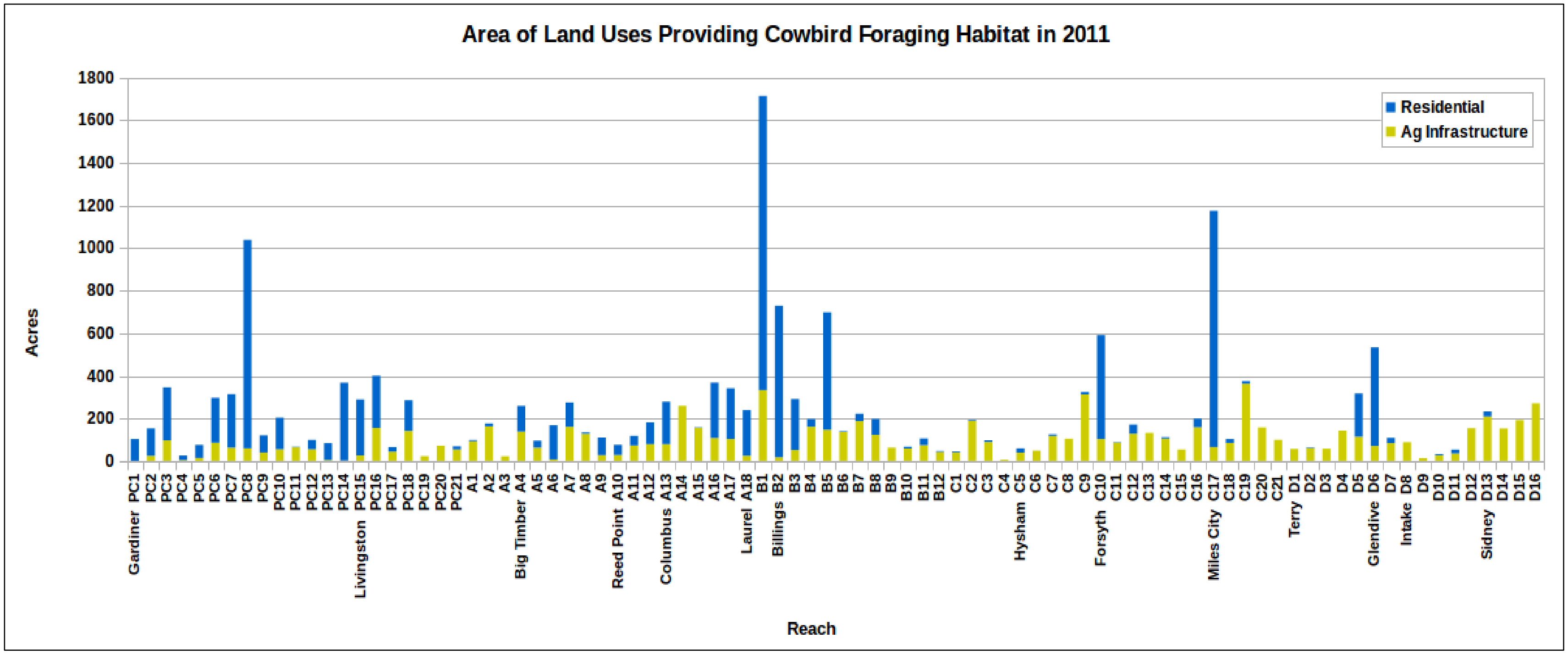


Figure 4-157 Areas of Residential land use (Exurban Residential + Urban Residential) and Agricultural Infrastructure (e.g., feedlots, corrals, etc.) within each reach in 2011

Note: *These land uses represent prime foraging habitat for Brown-headed Cowbirds*

4.10.8.2 Change in the Extent of Land Use Providing Cowbird Habitat

From 1950 to 2011, the extent of residential development in the floodplain increased from less than 3,000 acres to greater than 10,000 acres. Much of the residential development occurred in Regions PC and B. Acreage in each of these regions increased from approximately 500 acres in 1950 to more than 3,000 acres in 2011. In Regions PC and A, the greatest increases occurred between 1976 and 2001, when acreage more than doubled. In Region B, the greatest increase occurred between 1950 and 1976. Although Region C had the greatest extent of Residential in 1950, relatively little acreage (less than 1,000 acres) was gained through time. Extent of Residential in Region D was lowest of all regions, and has remained relatively steady since 1976 at approximately 700 acres. (Section 4.2.4.4, Land Use provides a more complete discussion of changes in Urban and Exurban development within reaches of the river.)

The approximate extent of AgInf in the floodplain increased from 3,700 acres in 1950 to 8,500 acres in 2011. Acreage more than doubled in that time period in all regions except B. In Region C, the greatest increase in AgInf occurred between 1950 and 1976, while the greatest increase occurred between 1976 and 2001 in Region D. All other regions experienced relatively steady increases in AgInf through time.

4.10.8.3 Relevant Trends in Distribution of Avian Responses (Land Use and Cowbird Parasitism)

- The extent of land uses providing foraging habitat for Cowbirds was greatest in the upper regions of the river and lowest in the lower regions. These results are consistent with results from the avian data; Cowbird abundance was highest in Regions PC and A, and lowest in Region D.

- More Cowbird host species (i.e., those species that are negatively impacted by parasitism), particularly species that are also conservation species, occurred in the lower regions of the river. The extent of land use providing Cowbird foraging habitat was lowest in those regions, suggesting that currently the impact of parasitism in those lower reaches may be relatively low compared with the upper reaches. However, future increases in land use that result in greater Cowbird abundance in Regions C and D may be especially detrimental because so many Cowbird host species of conservation concern occur there.

- Ovenbirds and Black-and-white Warblers (both PSOC) are Cowbird host species that occurred more often in Regions C and D, where the extent of land use providing Cowbird foraging habitat was lowest in 2011. Consequently, these species currently experience lower risk of negative impacts of parasitism.

- Veerys (SOC) are a Cowbird host species that occurred only in Region PC, where the extent of land use providing Cowbird foraging habitat was greatest of all regions in 2011. The amount of residential development in Region PC increased from approximately 500 acres in 1950 to almost 3,500 acres in 2011, with substantial increases (>500 acres) in the last 10 years (2001-2011), suggesting that residential development may continue to increase in the future. Consequently, Veerys may be at higher risk of negative impacts of parasitism compared with species that occur in other regions, and the negative impacts may continue to increase for Veerys in the future.

4.10.8.4 Extent of Cottonwood Forest Potentially Impacted by Cowbird Parasitism

When breeding habitat is closer to foraging habitat, Cowbirds spend less energy commuting and have more energy reserves for laying eggs. Consequently, breeding habitat in closer proximity to foraging habitat may experience greater intensity of parasitism. Cottonwood forest within 500 meters (1,640 feet or 0.3 miles, i.e., “highly impacted”) and 1 kilometer (3,280 feet or 0.6 miles, i.e., ‘impacted’) of land uses that provide Cowbird foraging habitat is potentially degraded by high rates of parasitism. The land use categories identified in Section 4.10.8.1 (Residential and AgInf) were buffered by 500 meters (1640 feet) and 1 kilometer (3,280 feet), then overlaid with the Riparian Habitat Map (DTM and AGI 2008a) to project the extent of potentially degraded cottonwood forest habitat within the riparian corridor of the Yellowstone River in 2001 (the most current habitat data).

For almost every reach (all but C4 and C15) at least one-third of cottonwood forest in the reach was potentially impacted by Cowbird parasitism (i.e., within 1 kilometer/.6 miles of land use), and in 80 percent of reaches more than half of the cottonwood forest was potentially impacted. Reach C4 had the smallest amount of habitat potentially impacted (only 18 percent within 1 kilometer/.6 miles of land use), while Reach A4 had the greatest (100 percent of cottonwood forest highly impacted).

Most of the reaches in Region A had a high percentage of cottonwood forest that was impacted by parasitism (90 percent on average), and most of that forest was highly impacted. Almost all of the cottonwood forest habitat in reaches B1 through B6 was also potentially impacted. On average, reaches of Region C had less than 75 percent of cottonwood habitat potentially impacted, and less than 30 percent highly impacted; however, all of the forest in Reaches C17 through C19 was potentially impacted. Reaches in Region D had on average the lowest percent of forest potentially impacted by parasitism (less than 60 percent), with less than 20 percent of that habitat highly impacted.

Across all regions, a greater percentage of cottonwood forest habitat was potentially impacted by parasitism due to AgInf land use than Residential in 2001. The impact was greatest in Regions A and B, where >80 percent of forest was within 1 kilometer (0.6 miles) of AgInf. The percent of cottonwood forest potentially impacted by Residential was highest in Region A (almost 50 percent) and lowest (less than 10 percent) in Region D. However, the areal extent of each land use type was not always proportional to the potential impact of each land use on cottonwood forest habitat. For example, in Regions A and B, Residential land use occupied many more acres of land than did AgInf in 2001, but AgInf impacted a much greater percentage of cottonwood forest in those regions. Therefore, the potential impact of land use on habitat condition reflects more than just the total extent of land uses present in the landscape; the amount and distribution of cottonwood habitat in the floodplain will influence this metric, as well as the density of land use and the location where it occurs. AgInf is more widely distributed in the floodplain and is often located closer to riparian habitat than Residential land use, which likely accounts for the greater proportion of cottonwood forest potentially impacted by this land use.

Figure 4-158 presents the amount of cottonwood forest habitat with low risk of cowbird parasitism (i.e., >1 kilometer/.6 miles from land use) for each reach of the river in 2001. On average, reaches in Regions A and B had the least acreage of ‘low risk’ habitat (less than 10 acres/valley mile), while reaches in Region D had the greatest (more than 70 acres/valley mile). Very little ‘low risk’ habitat existed upstream from Reach B6, while reaches D16 and D11 contained the greatest amounts of ‘low risk’ habitat (> ~250 acres/valley mile). Most of the reaches with greater than 100 acres/valley mile of ‘low risk’ habitat were anabranching (UA and PCA) reaches in Regions C and D, likely reflecting the greater amount of forest generally found in these reach types as well as the lower intensity of land use in these regions.

4.10.8.5 Change in the Extent of Habitat Impacted by Cowbird Parasitism

In 2001, most reaches of the river had less cottonwood habitat with low risk of parasitism compared with 1950. However, reaches C4, C6 and most reaches downstream from D9 experienced substantial gains in the acreage of cottonwood habitat that had low risk of parasitism. Reaches in Regions C and D generally experienced net losses in the amount of habitat with low risk of parasitism from 1950 to 1976, followed by net gains from 1976 to 2001. This likely reflects changes in forest cover that occurred in these regions;

reaches in Region C gained substantial acreage of Open Timber forest during this time, while reaches in Region D gained acreage of Closed Timber (Section 4.7.3, Terrestrial Plants).

Although the extent of AgInf was more than three times greater in 2001 compared with 1950, the percent of habitat impacted by AgInf during that same time period generally remained steady in all regions of the river. For example, Region D gained over 1000 acres of AgInf between 1950 and 2001, but the percentage of forest potentially impacted by AgInf remained relatively steady. This is likely because reaches of Region D experienced large net gains of cottonwood forest between 1976 and 2001 that were not observed in the previous time period (DTM and AGI 2008a, Section 4.7.3, Terrestrial Plants); an increase in the extent and influence of AgInf land use from 1976 to 2001 may have been offset by an increase in the total amount of cottonwood forest available in the region. Conversely, changes in the areal extent of Residential land use from 1950 to 2001 generally reflected changes in the percent of cottonwood habitat impacted by Residential during that same time period. This again emphasizes that the potential impact of land use on habitat condition reflects more than just change in the total extent of land use.

Almost 50 percent of the cottonwood forest in Region A was potentially impacted by Residential in 2001, and this was three times the amount potentially impacted in 1950. In the other regions, the percent of cottonwood forest potentially impacted by Residential doubled from 1950 to 2001; however, in Region D the amount in 2001 was still less than 10 percent.

4.10.8.6 Relevant Trends in Distribution of Avian Responses (Habitat Extent and Cowbird Parasitism)

- The percent of cottonwood forest impacted by parasitism was greatest in the upper regions of the river and lowest in the lower regions. These results are consistent with results from the avian data; Cowbird abundance was highest in Regions PC and A, and lowest in Region D.

- The intensity of parasitism was greatest in cottonwood forests of Region A, where a large percentage of forest was highly impacted. These results are consistent with results from the avian data; three times as many Cowbirds were observed on average at sites in Region A compared with Region D.

- Most of the cottonwood habitat with low risk of parasitism in 2001 was located in the lower reaches of the river; very little acreage occurred in Regions A or B. This suggests that cottonwood forest located in Regions C and D may provide the last remaining habitat with low risk of Cowbird parasitism along the river. This is particularly important because most of the Cowbird host species of conservation concern occur in these regions. Consequently, future changes in land use in Regions C and D that result in a greater proportion of forest impacted by parasitism in those regions may be especially detrimental for Cowbird host species.

- Ovenbirds and Black-and-white Warblers (both PSOC) are Cowbird host species that occurred more often in Regions C and D.

- Veerys (SOC) are a Cowbird host species that occurred only in Region PC, where habitat data did not exist for quantifying the amount of forest potentially impacted by parasitism. However, Cowbird abundance was high in Region PC, and trends in the amount of habitat impacted in this region are likely similar to trends observed in Region A, where very little unimpacted forest remained in 2001. Consequently, future changes in land use in the upper reaches of the river that result in degradation of the last remaining unimpacted habitat, or cause increased intensity of parasitism, may be especially detrimental for Veerys.

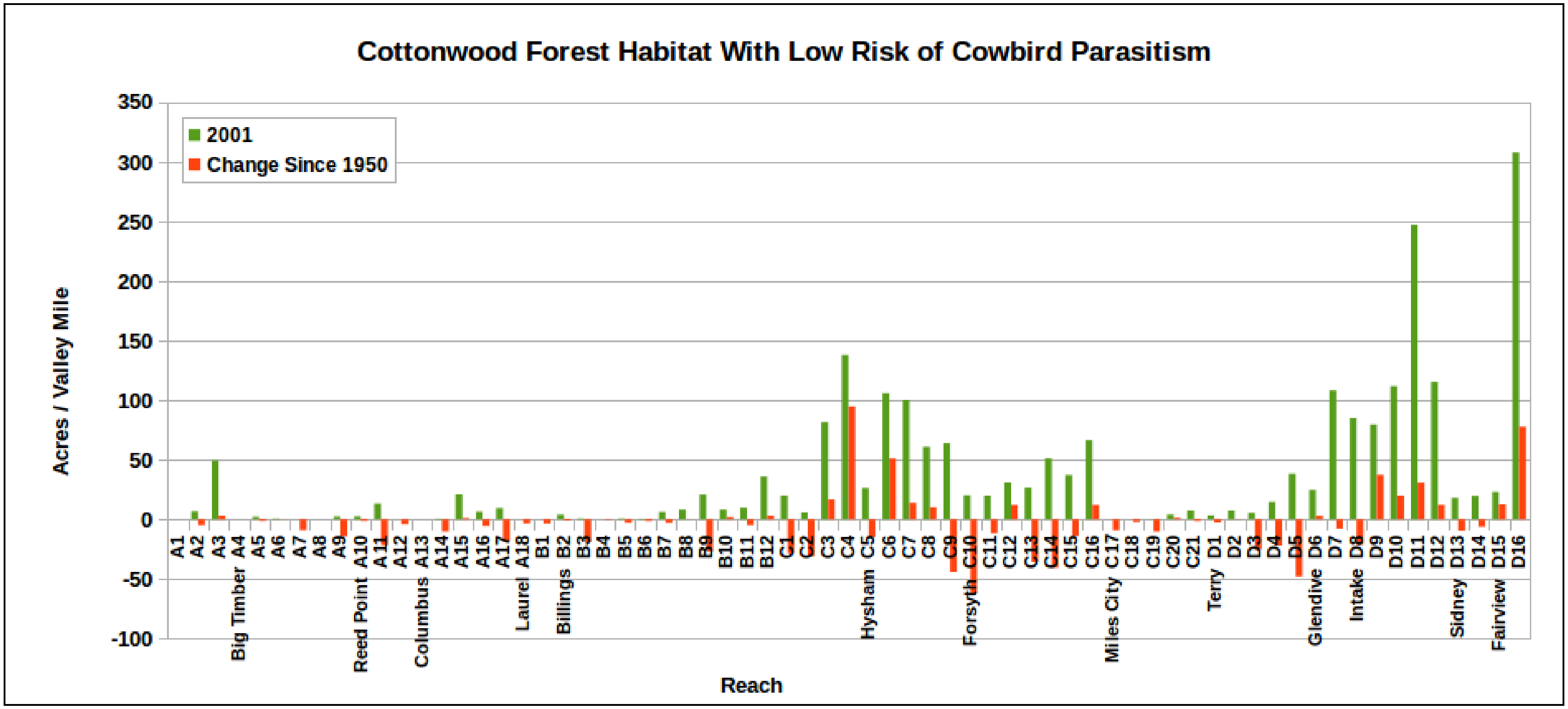


Figure 4-158 **Extent of cottonwood forest habitat with lowest risk of cowbird parasitism (i.e., forest habitat greater than 1 km/.6 mile from Residential or Agricultural Infrastructure land uses) for reaches in 2001, and change in acreage since 1950**

4.10.9 Spread of Invasive Plant Species

If monotypic stands of saltcedar or Russian olive completely replace structurally complex native cottonwood forest, habitat condition will be degraded for many riparian bird species. Monotypic stands of Russian olive and saltcedar have few large trees and snags and lack the forest canopy layer provided by native cottonwood habitats. Consequently, riparian habitats dominated by these invasive species usually support fewer bird species that nest and forage in the canopy strata, while cavity-nesting and bark-gleaning species that depend upon large trees are consistently absent.

Large live and standing dead trees are also a crucial component of habitat for many non-avian species that occur in riparian forest along the Yellowstone River. For example, Hoary Bats (*Lasiurus cinereus*), a Montana SOC, roost in dense riparian forest canopy and hibernate in hollow trees, while Silver-haired Bats (*Lasionycteris noctivagans*), a PSOC, roost and breed in old woodpecker cavities. Porcupines (*Erethizon dorsatum*) and White-footed Mice (*Peromyscus leucopus*), also Montana PSOC, use hollow trees in riparian forest for foraging and denning.

4.10.9.1 Extent and Distribution of Invasive Plant Species

Metrics that represent the extent of monotypic Russian olive and saltcedar in the floodplain may be indicators of habitat degradation for forest canopy and cavity-nesting species. The distribution of Russian olive and saltcedar was evaluated in Section 4.7.10 (Terrestrial Plants). In summary, the extent of Russian olive was mapped in 2008 for all counties along the river corridor; the greatest extent was documented in Region C, while Region B had the greatest concentration. Relatively low densities of Russian olive occurred in Regions A and D. There are no comprehensive studies that quantify the distribution of saltcedar along the entire Yellowstone, but limited data suggest that saltcedar generally occurs as an incidental community type most frequently in Regions C and D.

4.10.9.2 Change in the Extent of Invasive Plant Species and Potential Human Influences

No data exist to quantify how the distribution of Russian olive or saltcedar has changed through time. However, because they are exotic species and did not originally occur in riparian areas of Montana, the current distribution can be said to reflect an increase from historical baseline conditions.

Change in floodplain processes that influence the extent and distribution of invasive species may also provide insight about potential trends. Russian olive and saltcedar have a competitive advantage over native species when natural hydrologic regimes are modified by land use, and invasion by Russian olive and saltcedar is often enhanced along river systems with altered hydrology (see Section 4.7.10, Terrestrial Plants). Consequently, the documented changes in hydrology (Section 4.3, Hydrology), as well as changes to the riparian processes driven by hydrology that maintain cottonwood succession, indicate there has likely been habitat degradation for birds due to the spread of invasive species.

Section 4.7.10 includes a thorough discussion of the potential impacts of hydrologic alterations on the spread of invasive plant species, and human influences of change. In summary, decreases in late summer low flows that are documented along the Yellowstone River (discussed in Section 4.3.3, see Figure 4-38) may cause moisture stress to native riparian plants and provide more favorable conditions for infestation by more drought tolerant invasive species. These alterations are most evident in Regions C and D and may consequently influence the further spread of invasive species in those regions. Floodplain turnover is a river process that is a driver of disturbance and successional processes that maintain native plants. A decline in the rate of turnover would suggest a change in conditions that are detrimental for cottonwood recruitment and favorable for the expansion of Russian olive and saltcedar. Riparian turnover was quantified for the Yellowstone River for 1950 through 2001 (Section 4.7.5 and Section 4.5.3.4). The rate of floodplain turnover from riparian cover to channel has declined since 1950, suggesting that conditions for the recruitment of native riparian plants may be degraded, while conditions for the establishment of invasive plant species may be enhanced. This indicates that habitat condition for forest canopy and cavity-nesting species may be degraded if floodplain turnover rates continue to decline in the future and the extent of monotypic stands of invasive species increases in the floodplain.

4.10.9.3 Relevant Trends in the Distribution of Avian Responses (Invasive Species)

- More than 20 percent of the riparian bird species observed along the Yellowstone River are cavity-nesting species that use large trees and snags for foraging and nesting. If native cottonwood forest is replaced by monotypic stands of Russian olive or saltcedar that lack large trees, these cavity-nesting species could disappear from riparian habitats along the river, resulting in a decline in overall bird species richness in the riparian landscape.

- The greatest extent of Russian olive was documented in Regions B and C, while saltcedar has been documented primarily in Regions C and D. The distribution of these invasive species overlaps with the distribution of Red-headed Woodpeckers (SOC), which were observed in all sampled reaches downstream from B7, and Chimney Swifts (PSOC) which were observed in select reaches of Regions C and D. Consequently, further expansion of Russian olive and saltcedar that corresponds with a loss of cottonwood habitat in these lower reaches of the river could have negative impacts for these species of concern.

4.10.10 Loss and Degradation of In-channel and Aquatic Habitat

Federally endangered Least Terns have been documented breeding along the Yellowstone River downstream from the Tongue River confluence. The following information about Terns was summarized from Atkinson and Dood (2006). Nesting habitat includes midstream sand and gravel bars relatively free of vegetation, while foraging areas include side channels and other shallow water habitats (<1 meter deep, ideally approximately 15 cm deep) where small surface schooling fish congregate. Essential breeding habitat includes areas that contain foraging habitat in close proximity to nesting sites. Consequently, most breeding sites along the Yellowstone River occur in unconfined or braided sections where channel sinuosity is high and there is greater incidence of bars and islands surrounded by channel.

4.10.10.1 Change in the Extent and Quality of In-channel and Aquatic Habitat and Human Influences

Likely human influences of changes to Least Tern habitat are presented in Table 4-21. In summary, alterations to hydrology that cause reduced floodplain complexity and a decline in floodplain disturbance will have the greatest impact on the extent and quality of habitat for Least Terns. The loss of midstream sand and gravel bars used for nesting, as well as the loss of shallow water secondary channels used for foraging, occurs when complexity is reduced in the floodplain. Alterations in hydrology that may result in reduced floodplain complexity include reduced peak flows and reduced summer low flows; these alterations have been observed along the Yellowstone River (Section 4.3.3, Hydrology). Since 1950, the extent of mid-channel bars has declined by 1100 acres (43 percent) in Regions C and D, while approximately 40 miles of secondary channels surrounding bars have been lost (Figure 4-68 and Figure 4-69, Section 4.5.3.2, Geomorphology). A decline in the input of sediment below the Bighorn River confluence also contributes to the decline in extent of mid-channel bars. Furthermore, a reduction in the frequency and intensity of flood scour during peak flows allows for the encroachment of vegetation on existing sand and gravel bars. This represents a decline in the extent of prime nesting and foraging habitat for Least Terns along the river.

Floodplain isolation, particularly the isolation of the 5-year floodplain that most represents the active riparian corridor, results in the loss of connectivity with secondary channels and larger side channels that provide crucial foraging habitat (Section 4.4.3.2, Hydraulics). Isolation of the floodplain has caused a contraction in the extent of inundated area that has largely impacted shallow water secondary channels in unconfined reaches of the river; these areas are most crucial for providing foraging habitat for Terns.

Physical floodplain features such as bank armor restrict natural lateral channel migration, which also contribute to a loss of floodplain complexity. There are approximately 136 miles of bank armor along the Yellowstone River (Section 4.5.3.6, Geomorphology). The construction of these features may be especially detrimental in reaches that are naturally unconfined in Regions C and D, because these reach types provide the most floodplain complexity and likely provide the greatest extent of nesting and foraging habitat for Least Terns.

4.10.10.2 Relevant Trends in the Distribution of Avian Responses (Aquatic Habitat)

- Least Terns have been documented in various river reaches of Regions C and D, particularly downstream from Miles City (Atkinson and Dood 2006).

- Isolation of the 5-year floodplain is most prominent in Regions C and D; contraction of the active riparian corridor represents a potential loss of habitat area for Least Terns. The decline of mid-channel bars and secondary channels, which represent essential breeding habitat for Least Terns, is also substantial in these regions.

5.0 SOCIOECONOMICS

5.1 Introduction

This chapter describes socioeconomic conditions in the study area. It includes profiles of the 12 counties in the Yellowstone River Corridor, describes primary economic sectors and demographics, and summarizes results of a cultural values survey conducted in the study area. The study corridor covers a geographically and economically diverse area. The region shares a unique history and is culturally important. While each County is distinct, together, they are facing many of the same opportunities and uncertainties moving into the future. It should be noted that all economic data is reported at county levels and thus differs from the analysis in other parts of the report which is specific to the river corridor and the adjacent lands.

To help distinguish the county-level analysis from the data in the rest of the study, the 12 counties that intersect the river corridor (river corridor counties) have been grouped into five segments that reflect economically similar areas (Figure 5-1). While these loosely correlate to the study Regions described in Chapter 3, they should not be used interchangeably. Some report sections below present information at the segment level, while others present at the county level. It should be noted that the segments are the same geographic groupings applied in the Yellowstone River Cultural Inventory Report.

Although a summary of the socioeconomic conditions in the study area is provided below, more detailed information is available in Appendix 10 (Socioeconomics), which includes sector analysis, regional economic profiles, and a cultural inventory. **Note that the segment numbering in this chapter has been modified to be consistent with the regions used in the rest of this report; numbered from upstream to downstream. This is opposite from the numbering in Appendix 10.**

5.2 Segment Overview and Trends

The 12-county river corridor is both historically and culturally significant. The area was explored during the Lewis and Clark Expedition, with several important historical landmarks located throughout the corridor (National Park Service 2014a). Clark traversed the bulk of the river valley, from present-day Livingston to its confluence with the Missouri River in North Dakota, while Pompey's Pillar, located in Yellowstone County, bears the signature of William Clark, signed on his journey home following the expedition (National Park Service 2014b). Many of the counties in the river corridor served as important railroad and mining camps during the early twentieth Century (Montana Department of Labor and Industry 2012a; Jones Lang LaSalle 2013). The Enlarged Homestead Act of 1909 promoted the settlement of many of the eastern counties and the expansion of agriculture in the region (Eastern Plains Economic Development Corporation 2006). Counties within the corridor are home to two tribal reservations, the Northern Cheyenne Tribe (Big Horn and Rosebud counties) and the Crow Tribe (Yellowstone and Big Horn counties) (Montana State Governor's Office of Indian Affairs 2013; Northern Cheyenne Tribe 2013).

Today, counties in the Yellowstone River Corridor are experiencing an increase in the diversity of economic sectors driving local economies. Natural resource extraction and agriculture drive the economy of many communities within the river corridor. The Bakken Oil Field is having notable effects, coal mines continue to be an important source of employment, and coal and metal mines are still fully operational (Southeastern Montana Development Corporation 2010; Bohnenkamp et al. 2011; Montana Department of Labor and Industry 2012b). In addition to extractive natural resource industries, counties along the corridor are well known for abundant recreation opportunities. Yellowstone National Park and Custer-Gallatin National Forest, several blue ribbon streams and rivers, as well as over a hundred lakes and reservoirs make the counties along the river corridor a heavily-used area for recreation. These recreation-based industries are viewed as important economic drivers for several counties within the corridor (Northern Rocky Mountain Economic Development District 2012). In the future, the continued development of extractive industries may conflict with the emerging tourism and recreation industries.

5.2.1 Segment 1 – Park County, MT

Segment 1 of the river corridor encompasses Park County, MT, so named for its proximity to Yellowstone National Park (Montana Department of Labor and Industry, 2012). Once an important stop for the Northern Pacific Railroad, the economy of Park County now includes agriculture, logging, and mining, as well as recreation and tourism related to Yellowstone National Park and the other surrounding natural resources (Park County Montana, 2013a).

Following the Lewis and Clark Expedition, the first economic development of the area that would become Park County was centered on fur trapping with its abundant population of wildlife, specifically beavers (Park County Montana, 2013b). Late in the 19th Century, the Northern Pacific Railroad Company helped to establish the town of Livingston, MT, located in Park County. It also provided an early gateway to Yellowstone National Park with a branch line from Livingston to Gardiner. Livingston would serve as the company's repair and maintenance depot, and at one point employ over 1,100 residents at the peak of Livingston's population (City of Livingston Montana, 2008). Following the boom of the 1950s, the railroad industry began to decline as highways and cars became the chosen method of transportation.

With the railroad no longer playing such an active role in the economy of Park County, industries associated with recreation and tourism have begun to drive the local economy. The original, and only year-round, road access to Yellowstone National Park is located in Park County. In addition to Yellowstone National Park, Park County is home to over 100 mountain peaks, the Yellowstone and Shields Rivers, and over 160 lakes and reservoirs (Park County Montana, 2013a). These natural resources are helping to attract local business that can cater to the growing tourism industry. In 2011, 4 of the top 10 industries in Park County were related to recreation and tourism (Montana Department of Labor and Industry, 2012). The recreation and tourism industry is viewed as an important element in the continued growth of the Park County economy. One of the goals of the Northern Rocky Mountain Economic District (encompassing both Park and Gallatin Counties) is to, "build on our unique natural assets to develop and enhance our tourist industries" (Northern Rocky Mountain Economic Development District, 2012). Tourism will likely continue to play an essential role in the growing economy of Park County.

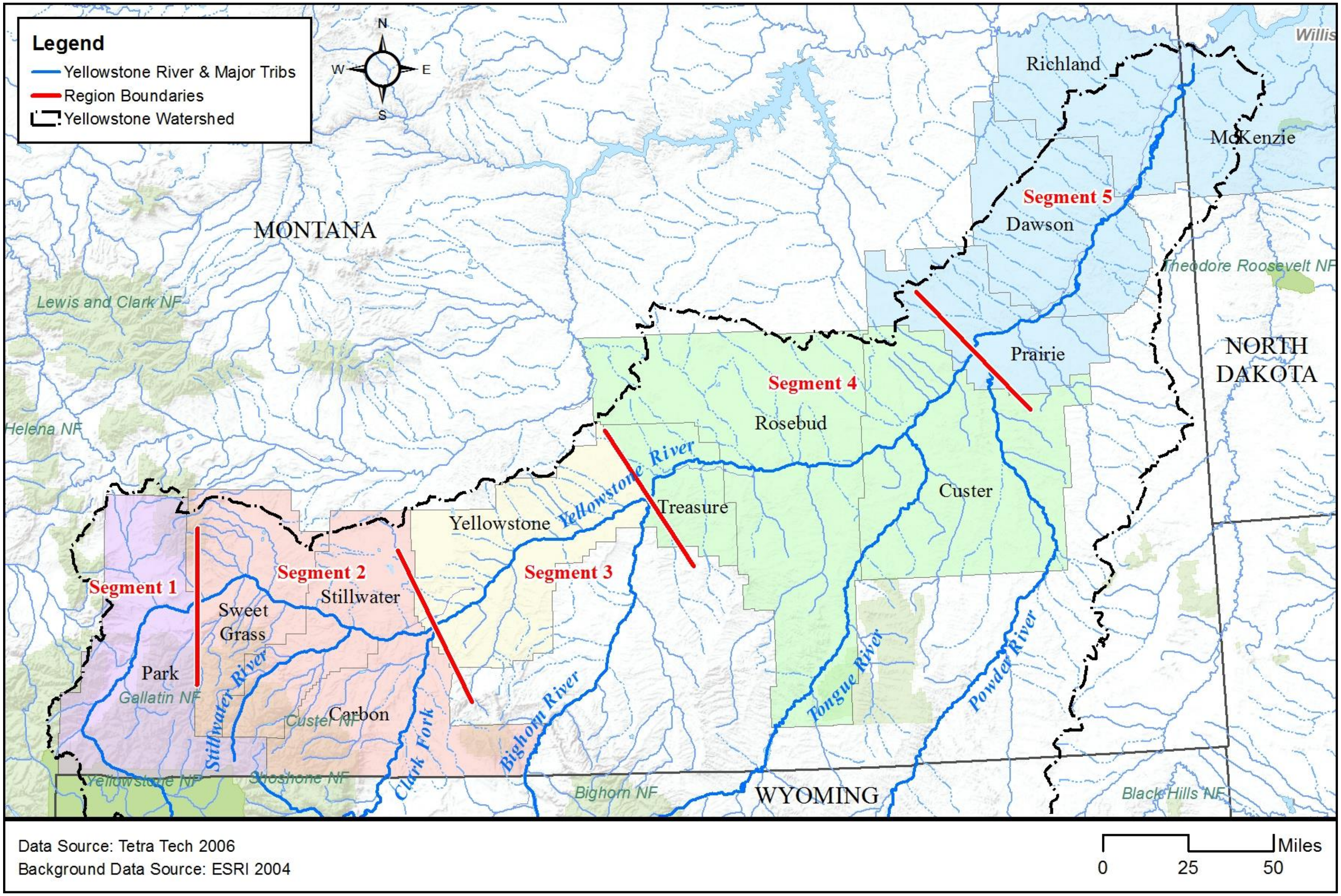


Figure 5-1 Corridor segments as economically similar areas

5.2.2 Segment 2 – Sweet Grass, Stillwater, and Carbon Counties, MT

Segment 2 of the Yellowstone River corridor consists of Sweet Grass, Stillwater, and Carbon Counties, located in south central Montana. The geography of the area is diverse and includes several mountain ranges, prairies and grasslands, as well as two blue ribbon trout streams, the Boulder River and Yellowstone River. The economy of these three counties is currently changing, shifting from a primary focus on extractive natural resource activities, including mining and agriculture, to include recreation and tourism-based activities (Montana Department of Labor and Industry, 2012a).

All three counties found in Segment 2 have a rich history associated with natural resource extraction. Until recently, mining was the primary industry of Carbon County (Montana Department of Labor and Industry, 2012a; Carbon County, 2014). Mining was, and is, still an important industry in both Stillwater and Sweet Grass Counties, with platinum and palladium being key resources (Montana Department of Labor and Industry, 2012b).

In 2010, agriculture, forestry, fishing and hunting accounted for 16 percent of total average employment across the three counties (Bureau of Economic Analysis, 2010). According to the 2012 Census of Agriculture, over 67% of total land in the three counties is under agricultural production (United States Department of Agriculture, 2012). Sweet Grass County is an important producer of livestock, including cattle and sheep, and dryland crops such as hay, wheat, barley and oats (Montana Department of Labor and Industry, 2012c).

Given the abundant natural resources located in Segment 2, recreation and tourism is an important element in the local economy of the three counties. Resorts and public facilities offer trout fishing, hiking, mountaineering, cross-country and alpine skiing. The segment also serves as a gateway to Yellowstone National Park. The tourism industry is gaining importance in the economies of all three counties in Segment 2.

5.2.3 Segment 3 – Yellowstone County, MT

Segment 3 of the Yellowstone River corridor encompasses only Yellowstone County, MT. Yellowstone County is known by the historical landmark Pompey's Pillar, as well as its cultural importance to the Crow Nation. The city of Billings is also located in Yellowstone County and is the largest city in both the county as well as the state of Montana.

The Apsaalooké, or Crow, Reservation is located in Yellowstone and Big Horn counties and is the largest reservation in Montana, encompassing over 2 million acres of land. Of the 10 thousand enrolled tribal members, about 7.5 thousand live on or near the reservation (Montana State Governor's Office of Indian Affairs, 2013). The tribal economy is dependent on both energy and agriculture, in the form of coal mine royalties, a small dryland farming operation, and a small buffalo herd. (Montana State Governor's Office of Indian Affairs, 2013). In 2005, the reservation had an unemployment rate of 46.5 percent, compared to a state reservation average of 51.6 percent (Montana State University Extension, 2011a). In 2000, the poverty rate on the reservation (30.5 percent) was almost the same as the average across all Montana tribal reservations (30.4 percent) (Montana State University Extension, 2011a).

Spurred on by the expansion of railroads as well as the Enlarged Homestead Act, the city of Billings evolved as an economic hub in the early 20th Century (Jiusto, 2014). Today, Billings continues to serve as an important economic center for Yellowstone County and the state of Montana. In 2010, over 10 percent of the total population of Montana was located in Billings (United States Census Bureau, 2012). Additionally, as of 2007, over 10 percent of the firms in the state of Montana were located in Billings (United States Census Bureau, 2012). With the expansion of the Bakken Oilfields to the east, continued commercial growth and expansion is anticipated for both the city of Billings and Yellowstone County (Falstad, 2012).

5.2.4 Segment 4 – Treasure, Rosebud, and Custer Counties, MT

Segment 4 of the river corridor encompasses a three-county area: Treasure, Rosebud, and Custer Counties, MT. Similar to Segment 5, the three-county area of Segment 4 is sparsely populated, with this regional economy highly dependent on agriculture (including timber) and energy development (coal, coal-bed methane, oil) (Southeastern Montana Development Corporation, 2010).

Additionally, Segment 4's Rosebud County includes a portion of the Northern Cheyenne Reservation, the remainder of which is in Big Horn County. The reservation is over 444 thousand acres and is home to nearly 5 thousand of the 10 thousand enrolled tribal members (Northern Cheyenne Tribe, 2013). In 2000, the poverty rate among reservation residents was above 46 percent with 1 in 4 residents over the age of 25 not having earned at least a high school diploma; in 2005, nearly 60 percent of residents of the reservation were unemployed (Montana State University Extension, 2011b).

5.2.5 Segment 5 - Prairie, Dawson, Richland Counties, MT, and McKenzie County, ND

Segment 5 of the Yellowstone River corridor encompasses a four-county area, spanning Prairie, Dawson, and Richland Counties in Montana as well as McKenzie County in North Dakota. Historically, this area is known for both its agricultural importance as well as its rich oil and gas resources. Population increased due to the development of an agricultural industry via The Enlarged Homestead Act of 1909, which increased farming and ranching in the region. Another more recent population boom was triggered by the discovery of the Bakken Oil Field.

After peaking in the 1980's the economic boom driven by the oil and gas industry experienced a downturn during the 1990's, coincident with drought conditions and a poor agricultural economy through much of the 2000s. However, the oil and gas sector recently experienced a boom due to the advancement of extraction methods. The oil and gas sector is a driver of change in eastern Montana and western North Dakota, resulting in high rates of net in-migration, increased job opportunities, increased tax revenue, and an increase in the population in areas that have previously experienced net out-migration. Though there may be uncertainty regarding the specific changes the four-county study area will experience in the future, it is certain that this area will continue to develop given the continued influence of the agriculture and oil and gas sectors.

5.3 Demographics Overview

The following summarizes demographic characteristics and trends for all twelve counties in terms of population and age. Table 5-1 presents population totals for all counties (U.S. Census Bureau, 2010).

Table 5-1
Population Totals by County, 1950-2010

	1950	1960	1970	1980	1990	2000	2010	Percent change (1950 to 2010)
Segment 1								
Park County, MT	11,999	13,168	11,197	12,869	14,562	15,694	15,636	30%
Segment 2								
Sweet Grass County, MT	3,290	3,621	2,980	3,216	3,154	3,609	3,651	10%
Stillwater County, MT	5,416	5,526	4,632	5,598	6,536	8,195	9,117	68%
Carbon County, MT	10,241	8,317	7,080	8,099	8,080	9,552	10,078	-2%
Segment 3								
Yellowstone County, MT	55,875	79,016	87,367	108,035	113,419	129,352	147,972	165%
Segment 4								
Treasure County, MT	1,402	1,345	1,069	981	874	861	718	-49%
Custer County, MT	12,661	13,227	12,174	13,109	11,697	11,696	11,699	-8%
Rosebud County, MT	4,155	6,187	6,032	9,899	10,505	9,383	9,233	122%
Segment 5								
Prairie County, MT	2,377	2,318	1,752	1,836	1,383	1,199	1,179	-50%
Dawson County, MT	9,092	12,314	11,269	11,805	9,505	9,059	8,966	-1%
Richland County, MT	10,366	10,504	9,837	12,243	10,716	9,667	9,746	-6%
McKenzie County, ND	6,849	7,296	6,127	7,132	6,383	5,737	6,360	-7%

Seven of the twelve counties have seen population decline between 1950 and 2010. Dawson and Carbon counties saw declines of less than 2 percent overall, but show different trends; the former has seen population gradually decline since 1960, while the latter has seen increased population since 1970. McKenzie, Richland, and Custer counties all experienced some decline over the period, but don't show as clear of a current trend. Prairie and Treasure counties both show substantial decline over the period, a consistent trend since 1960. Rosebud and Yellowstone counties had the greatest growth in population during this time period (U.S. Census Bureau 2010). Yellowstone County also accounts for the largest portion of the total population of the river corridor, with 63 percent of residents in the river corridor living in the segment. Stillwater and Park counties also showed strong growth over the period (U.S. Census Bureau 2010).

Segment 5 is the least populated segment in the river corridor, with 2.2 persons per square mile, while Segment 3 is substantially denser than any other segment in the river corridor, with 56.2 persons per square mile. Though most of the counties in the river corridor remain characteristically rural, Yellowstone

County is once again the exception. Park County has the second highest population density, with 5.6 persons per square mile (U.S. Census Bureau 2012).In addition to consideration of population, Table 5-2 presents median age by county for 1950 and 2010.

Table 5-2
Median Age by County, 1950 and 2010

	1950	2010	Percent Increase in Median Age (1950-2010)
Segment 1			
Park County, MT	32.9	45.4	38%
Segment 2			
Sweet Grass County, MT	32.2	46.6	45%
Stillwater County, MT	30.4	45.7	50%
Carbon County, MT	31.5	48.1	53%
Segment 3			
Yellowstone County, MT	28.8	38.8	35%
Segment 4			
Treasure County, MT	26.2	51.5	97%
Rosebud County, MT	27.8	36.5	31%
Custer County, MT	29.8	42.1	41%
Segment 5			
Prairie County, MT	28.0	53.6	91%
Dawson County, MT	27.7	43.5	57%
Richland County, MT	26.3	41.3	57%
McKenzie County, ND	27.4	38.0	39%
Source: U.S. Census Bureau, 2010			

All twelve of the counties experienced increased median age over the period. Seven of the counties saw increases of less than or equal to 50%, which the remaining counties saw increases of as high as 97 percent. The two highest increases, Prairie and Treasure counties, were the counties which experienced the largest declines in population over the period, possibly indicating out-migration and natural population change (Montana State University Extension, 2011c). Rosebud and Yellowstone counties experienced the largest increase in population over the period and experienced the least increase in median age, indicating that the counties are attracting new professional-age residents, likely to fill employment demand in the energy sector in Rosebud County.

5.4 Economic Indicators Overview

Table 5-3 summarizes personal income in the 12 counties in the study area. Yellowstone County has the largest population and the greatest total personal income and earnings by place of work in the river corridor, $5.6 billion and $4.2 billion, respectively, overwhelmingly influencing the river corridor totals (Bureau of Economic Analysis 2010). Yellowstone County has the second largest per capita income, $38 thousand. Segment 5, including Prairie, Dawson, Richland, and McKenzie counties, has the highest per capita personal income at $43 thousand, the second highest personal income and earnings by place of work, at just over $1 billion and $850 million, respectively (Bureau of Economic Analysis 2010).

Table 5-3
Personal Income, 2010

County	Personal Income (in Thousand $)	
	Per Capita	Total
Segment 1		
Park	34	527,320
Segment 2		
Sweet Grass	27	98,105
Stillwater	34	314,081
Carbon	34	340,837
Segment 3		
Yellowstone	38	5,609,050
Segment 4		
Treasure	34	24,182
Rosebud	35	324,526
Custer	34	401,252
Segment 5		
Prairie	31	36,563
Dawson	32	287,724
Richland	47	454,434
McKenzie	56	356,659
River Corridor Counties	**38**	**8,774,733**
Source: Bureau of Economic Analysis 2010		

The smallest total personal income is found Treasure, Prairie and Sweet Grass counties, while the smallest per capita personal income is in Sweet Grass County. Segment 4, including Treasure, Rosebud, and Custer counties, is the only segment where income from government payments exceeded property income in 2010 (Bureau of Economic Analysis 2010). Non-farm proprietors' (of sole proprietorships, partnerships, and tax-exempt cooperatives) income holds the largest share of proprietors' income in all segments, except for Segment 5 (Prairie, Dawson, Richland, and McKenzie counties), where farm proprietors' income (7 percent) exceeds non-farm proprietors' income (6 percent) (Bureau of Economic Analysis 2010).

Table 5-4 presents earnings by industry. The Bureau of Economic Analysis (BEA) includes suppressed data in total earnings. Data may be suppressed to avoid disclosure of confidential information or due to lack of confidence. For example, if in a county there is a single entity within a given industry, displaying industry level data would disclose that entity's data. This requires suppression of data within that industry, as well as additional industries, in order to eliminate the possibility of calculating suppressed data. The lack of confidence in the data may result from low or uncertain estimates and therefore is omitted.

Table 5-4
Earnings by Industry 2010 (in $1,000s)

	River Corridor Counties Total	Percent Total
Farm earnings	111,114	2%
Forestry, fishing, and related activities	8,501	0%
Mining	227,003	4%
Utilities	53,712	1%
Construction	474,975	8%
Manufacturing	310,939	5%
Wholesale trade	404,674	6%
Retail trade	470,257	8%
Transportation and warehousing	308,590	5%
Information	102,368	2%
Finance and insurance	278,587	4%
Real estate and rental and leasing	81,605	1%
Professional, scientific, and technical services	371,658	6%
Management of companies and enterprises	32,148	1%
Administrative and waste management services	166,574	3%
Educational services	31,762	1%
Health care and social assistance	895,034	14%
Arts, entertainment, and recreation	63,352	1%
Accommodation and food services	233,769	4%
Other services, except public administration	229,168	4%
Government and government enterprises	999,423	16%
Provided Data Total	*5,855,215*	*94%*
*Suppressed Data Total**	*400,858*	*6%*
Earning by place of work	6,256,069	100%

** Data not shown in order to avoid disclosure of confidential information, or where the estimate is uncertain (less than $50,000). Source: Bureau of Economic Analysis 2010*

Note that suppression of the data takes place at the county level. More information on the suppression of the data at the county level can be found in the socioeconomic appendix (Appendix 10). Government and Government Enterprises and various services sectors generally hold the largest share of earnings across all segments. Segment 2 (Sweet Grass, Stillwater, and Carbon counties) has the largest share of proprietors' employment (43 percent), followed closely by Park County (41 percent) (Bureau of Economic Analysis 2010). Government and Government Enterprises employ the largest percent of total employment in Segment 4 (Treasure, Rosebud, and Custer counties; 22 percent) and Segment 5 (Prairie, Dawson, Richland, and McKenzie Counties; 21 percent) (Bureau of Economic Analysis 2010).

A combination of services contributes to total employment in most counties. The accommodation and food services sector employs the greatest percentage of the workforce in Park County (14.6 percent), while the health care and social services sector is the major employer in Yellowstone (13.6 percent). Employment in retail trade is highest in Yellowstone County (12 percent), while farm employment is highest in Segment 2 (Sweet Grass, Stillwater and Carbon counties; 13 percent) and Segment 5 (Prairie, Dawson, Richland and McKenzie counties; 8.9 percent). Mining accounts for 7.1 percent of employment in Segment 5 (Bureau of Economic Analysis 2010) (Table 5-5).

Table 5-5
Employment by Industry, 2010

	The River Corridor Counties Total	Percent Total
Total Employment	**154,335**	
Wage and Salary employment	117,792	76%
Proprietors employment	38,388	24%
Farm proprietors employment	*5,286*	
Nonfarm proprietors employment	*33,102*	
Government and government enterprises	19,405	13%
Retail trade	17,670	11%
Health care and social assistance	17,163	11%
Accommodation and food services	12,769	8%
Construction	9,952	6%
Other services, except public administration	9,141	6%
Wholesale trade	6,883	5%
Professional, scientific, and technical services	8,223	5%
Farm employment	6,393	4%
Transportation and warehousing	5,371	4%
Finance and insurance	6,338	4%
Real estate and rental and leasing	6,441	4%
Administrative and waste management services	6,480	4%
Manufacturing	4,687	3%
Arts, entertainment, and recreation	4,272	3%
Mining	3,146	2%
Information	2,159	1%
Educational services	1,681	1%
Forestry, fishing, and related activities	429	0.30%
Utilities	483	0.30%
Source: Bureau of Economic Analysis 2010		

Table 5-6 shows the labor force for all the segments and the river corridor for year 2010. The number of individuals employed differs from Table 5-4 because of differences in data reported by the Bureau of Labor Statistics (BLS) and the BEA. The BEA estimates are adjusted to include some nonprofit organizations, students and their spouses employed by public colleges or universities, elected officials and members of state and local judiciary, interns employed by hospitals and by social service agencies, and insurance agents classified as statutory employees. Table 5-6 shows that, in 2010, Segment 5 had the lowest unemployment rate at 3.4 percent while Segment 1, Park County, had the highest unemployment rate at 7.5 percent.

Table 5-6
Labor Force, 2010

	Segment					The River Corridor Counties
	1	2	3	4	5	
Labor Force	8,332	11,740	80,992	10,450	14,099	125,613
Employed	7,710	11,105	76,820	9,887	13,620	119,142
Unemployment	622	635	4,172	563	479	6,471
Unemployment Rate	7.50%	5.40%	5.20%	5.40%	3.40%	5.2%
Source: Bureau of Labor Statistics, 2010						

5.5 Sector Contribution Analysis Summary

Today, counties in the river corridor are experiencing an increase in the diversity of economic sectors driving local economies. Natural resource extraction continues to drive the economy of many communities within the river corridor. The Bakken Oil Field is having notable effects on communities in Segment 5, coal mines continue to be an important source of employment for residents of the counties in Segment 4, and coal and metal mines are still fully operational in Segment 2. In addition to extractive natural resource industries, counties along the corridor are well known for abundant recreation opportunities. Yellowstone National Park, Gallatin and Custer National Forests, several blue ribbon streams and rivers, as well as over a hundred lakes and reservoirs make the counties along the river corridor a heavily-used area for recreation. These recreation-based industries are viewed as important economic drivers for several counties within the corridor, especially Park County (Segment 1) (Northern Rocky Mountain Economic Development District, 2012). In the future, the continued development of extractive industries may conflict with the emerging tourism and recreation industries.

The sector contribution analysis summarizes agricultural, exurban and urban development and transportation sector characteristics for each of the five segments, and then uses an economic input-output model to determine the contribution of specific economic sectors to a local or regional economy. The analyses were estimated using IMPLAN (Impact Analysis for Planning), a widely used model of this type of analysis. The IMPLAN platform was developed by the U.S. Forest Service and is now privately maintained and updated by the IMPLAN Group, LLC. The IMPLAN model draws upon data collected from multiple federal and state sources including the Bureau of Economic Analysis, Bureau of Labor Statistics, and the U.S. Census Bureau (Olson and Lindall, 1999).

Economic input-output models capture the complex interactions of consumers and producers of goods and services in local economies that arises from the interaction of multiple levels of producers and consumers. Direct effects measure the net amount of spending that stays in the local economy after the first round of spending for a product. Producers purchasing inputs from suppliers represent secondary spending. The income and employment resulting from these secondary purchases by input suppliers are the indirect effects within the economy. Employees of the directly affected businesses and input suppliers use their incomes to purchase goods and services. The resulting increased economic activity from employee income is the induced effect. The indirect and induced effects are known as the secondary effects. To determine the secondary effects, a combination of input, output and employment multipliers are calculated and will vary depending on the defined local area. The sums of the direct and secondary effects describe the total economic contribution of a sector in a local economy.

For the purposes of an economic contribution analysis, a region (and its economy) is defined as a functional economic area that includes primary labor markets and economic flows. Only spending that takes place within this regional area is included as contributing to economic activity. The size of the region influences both the amount of spending captured and the multiplier effects. For this analysis, separate models were run for the counties within each segment using the 2012 IMPLAN v3 county-level data profiles. Regional economic contributions from the IMPLAN model are reported for the following categories:

- Employment represents the number of jobs generated in the region from a sector in the economy. IMPLAN estimates for employment include *full time, part time, and temporary jobs.*
- Labor Income includes employee wages and salaries, including income of sole proprietors and payroll benefits.
- Value Added measures contribution to Gross Domestic Product. Value added is equal to the difference between the amount an industry sells a product for and the production cost of the product, and is thus net of intermediate sales.

The analysis and this discussion focuses on three sectors: transportation, agriculture, exurban and urban development. These three sectors were initially selected because they represented over 90% of land use conversion from natural to economic uses. Historical and current data for each segment along the river corridor are summarized and the results of the contribution analysis are presented. In some cases, data are provided at the county level to highlight important differences between the counties within a single segment, while in other cases, aggregate data are provided at the segment level. The full sector profile and economic contribution analysis can be found in Appendix 10 (Socioeconomics).

5.5.1 Transportation

5.5.1.1 Historical Introduction

In addition to the Enlarged Homestead Act, the railroads spurred population growth within the counties along the river corridor. The Northern Pacific Railroad helped to ensure that Miles City, located in Custer County, became an important cattle market for Southeastern Montana (Southeastern Montana 2012b). In 1909, Billings, Montana built a depot to be used by three railroad companies, the Northern Pacific, Great Northern, and the Chicago, Burlington, and Quincy, all three of which would be combined with two additional railroads to form the Burlington Northern, and eventually the Burlington Northern Santa Fe Railway (Burlington Northern Santa Fe 2013). Due to the number of homesteaders arriving, the railroads expanded and by 1931 more than 26 passenger trains went through the Depot daily (Billings Depot 2014).

The railroads helped form the city of Livingston, MT in Park County, in 1882. Livingston served as an important stop for the Northern Pacific (NP), as it was a midway point between St. Paul, Minnesota and Tacoma, Washington. The proximity of Livingston to Yellowstone National Park also made it a choice location for the railroad as the NP carried visitors to the Park. Finally, the construction of repair shops in town solidified Livingston’s importance to the railway. As automobiles increased in popularity, railroads shifted from transporting passengers to cargo (City of Livingston Montana 2008).

Though the railroads are no longer important carriers for passengers, they serve as an important link to markets for rural communities. Glendive, Forsyth and Laurel serve as train yards for the Burlington Northern Santa Fe Railway (BNSF) linking agricultural producers with Billings and interstate markets as well as providing distribution outlets for coal and oil. Additionally, the railway is a major employer within the county (Dawson County Economic Development Council). Billings, MT continues to serve as an important hub for the railroads, servicing both the BNSF and Montana Rail Link, operating a port facility and two intermodal facilities (Montana Department of Transportation 2013).

5.5.1.2 Current Transportation Description

In the state of Montana, between Livingston and Fairview, the railroad tracks stretch approximately 424 miles (personal communication with Diane Myers of Montana Department of Transportation). Two railroad companies currently operate within the Yellowstone River corridor counties, the Burlington Northern Santa Fe and the Montana Rail Link. Information about these companies was collected via published reports and interviews with representatives of the companies.

BNSF railroad tracks stretch through all the counties within the river corridor and has yards located in Laurel, Forsyth, and Glendive. BNSF reports that there were, on average, 20 trains per day through Forsyth in 2013. Overall, BNSF handled 1.2 million car loads in the state of Montana in 2013. Of the 1.2 million car loads, 343,000 car loads originated in the state and 34,000 terminated in the state. Of the carloads that originated in Montana, 244,000 car loads carried coal, 53,000 car loads carried agricultural products and 45,000 car loads carried industrial products. Most of the car loads of coal likely originated in southeastern Montana, as this is where many of the coal mines are located. Generally, a large volume of agricultural products originate in north central Montana with some also originating in the south eastern part of the state. Industrial products include crushed stone, lumber, chemicals and crude-oil related shipments, which primarily originate in the northwestern section of the state, with some recent growth in southeastern Montana (personal communication with Matthew Jones of Burlington Northern Santa Fe Railway).

Montana Rail Link operates between Livingston and Huntley in the river corridor, and reports that 40 percent of their payroll lives between Laurel and Livingston. The Laurel yard is utilized for car switching as well as train building (personal communication with Jim Lewis of Montana Rail Link).

In addition to the railroads, semi-trucks serve as an important means of freight transportation. The recent oil development in the Bakken Oil Field has increased the demand on the highways in southeastern Montana (Dybing et al. 2013). According to a recent report, Highways 16 and 200 have between 625 and 1407 average annual trucks per day near the town of Sidney, MT. The same can be seen on Interstate 94, near the town of Glendive, in Dawson County (Dybing et al. 2013). Given its midpoint location between Minneapolis and Seattle, as well as Denver and Calgary, Billings serves as a hub for freight transportation via trucking. The portion of Interstate I-94 that runs through Billings has an annual average daily traffic rate between 9,000 and 27,500 vehicles, with an estimated 22 percent semi-trucks (Kittelson & Associates Inc. and DOWL HKM Inc. 2014). The transportation industry components, both the railroads and trucking, provides economic activity in across the counties in the river corridor.

Two counties in the river corridor, Prairie and Treasure, receive more than 25 percent of their property tax revenue from the railroad. Most counties receive around 10 percent or less. Across the river corridor counties in Montana, 3 percent of total property tax revenue comes from the railroad, compared to 28 percent coming from residential property and 5 percent from agricultural land (Montana Department of Revenue 2012).

Current economic contributions of the railroad sectors were estimated in IMPLAN using total output values for two railroad-related sectors, railroad transportation and scenic and sightseeing transportation and support activities. Railroad Transportation includes industries that provide rail transportation of passengers and/or cargo using railroad rolling stock. Scenic and sightseeing transportation and support activities include transportation equipment to provide recreation and entertainment as well as support activities for rail transport. Economic contribution analyses address the importance or contribution of an existing industry to a local economy. Economic contributions of trucking were estimated in IMPLAN using the total output value for the sector transport by truck. Economic contributions of the railroad transportation and trucking sectors are reported in tables 5-7 and 5-8, while contribution of scenic and sightseeing transportation can be found in the Socioeconomic Appendix. Though outside the scope of this analysis, it should be noted that these transportation sectors support other industries within the River corridor counties, including but not limited to, agriculture, energy development and mining industries.

Table 5-7 and Table 5-8 summarize the results of the contribution analysis for railroad and trucking across all five segments. All results as presented are in 2012 dollars. In 2012, both railroad-related sectors contributed the most to the economy of Yellowstone County, MT, Segment 3. Railroad transportation contributed 1,400 jobs $88.0 million in labor income and nearly $208 million in value added while scenic and sightseeing transportation and rail support activities contributed 2,700 jobs, $115.0 million in labor income and nearly $144 million in value added. This is not surprising as Yellowstone County has three rail lines that pass through, Burlington Northern Santa Fe, Montana Rail Link and Signal Peak Energy.

Yellowstone County also houses one port facility and three intermodal facilities (Montana Department of Transportation, 2013). Railroads contributed the least in Segment 2 with both sectors contributing 5 jobs, total and less than $1 million in labor income or value added. In Segment 2, the BNSF (Burling Northern Santa Fe Railway) operates through Carbon County and the Montana Rail Link operates through Sweet Grass and Stillwater Counties, but there are not any port or intermodal facilities in any of the counties (Montana Department of Transportation, 2013).

Trucking also contributed the most to the economy of Yellowstone County, MT, Table 5-8. In 2012, transport by trucking contributed an estimated 3,200 jobs, $163.3 million in labor income and $228.3 million in value added. Trucking also contributed to the economy of the Prairie, Dawson, Richland, and McKenzie Counties. This is not surprising given the recent increase in trucking activity that can be attributed to the Bakken Oil Fields. Transport by truck in these counties contributed an estimated 2,700 jobs, $218.9 million in labor income and $300.8 million in value added to the economy. Transport by truck contributed the least in Park County, contributing an estimated 60 jobs, $2.3 million in labor income and $3.3 million in value added.

Table 5-7
2012 Transport by Rail Sector Contribution Summary

		Contribution (in millions)	
Segment & Impact Type	Employment	Labor Income	Value Added
Segment 1			
Direct	52	$5.5	$18.1
Secondary	86	$2.2	$3.9
Total	*138*	*$7.8*	*$22.0*
Segment 2			
Direct	2	$0.22	$0.03
Secondary	3	$0.07	$0.04
Segment 3			
Direct	400	$43.3	$141.2
Secondary	1.000	$44.7	$66.6
Total	*1,400*	*$88.0*	*$207.8*
Segment 4			
Direct	130	$13.5	$44.1
Secondary	170	$5.7	$9.5
Total	*300*	*$19.2*	*$53.6*

Segment & Impact Type	Employment	Contribution (in millions) Labor Income	Value Added
Segment 5			
Direct	300	$28.1	$91.8
Secondary	300	$15.7	$24.3
Total	*600*	*$43.8*	*$116.1*
Note: Results are contribution of Railroad Transportation. Contribution of Scenic and sightseeing transportation and support activities and be found in the Socioeconomics Appendix, segment numbering is opposite in the appendix.			

Table 5-8
2012 Transport by Truck Sector Contribution Summary

Segment & Impact Type	Employment	Contribution (in millions) Labor Income	Value Added
Segment 1			
Direct	40	$1.7	$2.4
Secondary	20	$0.5	$0.9
Total	*60*	*$2.3*	*$3.3*
Segment 2			
Direct	110	$5.3	$7.3
Secondary	40	$1.2	$2.2
Total	*150*	*$6.4*	*$9.5*
Segment 3			
Direct	1600	$99.6	$128.2
Secondary	1600	$63.7	$100.1
Total	*3,200*	*$163.3*	*$228.3*
Segment 4			
Direct	200	$10.8	$14.6
Secondary	100	$3.6	$6.5
Total	*300*	*$14.5*	*$21.1*
Segment 5			
Direct	1,900	$183.4	$239.1
Secondary	800	$35.5	$61.6
Total	*2,700*	*$218.9*	*$300.8*
Note: Results are sum of contribution of transport by truck in each segment.			

5.5.2 Agriculture

Beginning in the early 1900s, the Enlarged Homestead Act and Desert Act drove an increase in population and dry land agriculture in Eastern Montana (Barber 2012). The Enlarged Homestead Act allowed 320-acre claims of land, which made homesteading more attractive west of the 100th meridian. In addition to the Enlarged Homestead Act, the expansion of the railroad in Eastern Montana in the early 1900's, once again drove an increase in population (Barber 2012). The development of large-scale irrigation projects, enabled by Bureau of Reclamation in Dawson, Richland and Yellowstone counties, were also major contributors to agricultural growth.

Throughout the basin other important agricultural practices include: cattle and sheep ranching, wool production, sugar beet refineries, and livestock auctions. Irrigation projects continue to support crops including small grains, alfalfa and other hay crops, pasture, silage, beans and sugar beets.

Treasure, Rosebud, Prairie, and Richland counties had a substantial increase (57-92%) in irrigated acres between 1950 and 2010. Custer and Dawson counties experienced a slightly lower increase (19-35%), McKenzie and Park a minimal increase in irrigated land while all other counties along the river corridor saw a decrease in irrigated agricultural land from 1950 to 2012 (U.S. Department of Agriculture 2012) (Table 5-9 and Table 5-10).

Table 5-9
County Agricultural Statistics 2012

	Number of Farms	Land in farms (acres)	Ave. size of farm (acres)	Irrigated land (farms)	Irrigated land (acres)
Segment 1					
Park County	564	774,057	1,372	273	57,112
Segment 2					
Sweet Grass County	332	855,709	2,577	152	35,770
Stillwater County	593	809,443	1,365	179	21,557
Carbon County	726	791,295	1,090	431	72,781
Segment 3					
Yellowstone County	1,330	1,668,346	1,254	636	73,161
Segment 4					
Treasure County	109	617,635	5,666	59	21,907
Rosebud County	437	3,141,524	7,189	99	35,894
Custer County	423	2,189,930	5,177	175	30,315
Segment 5					
Prairie County	186	769,046	4,135	45	9,240
Dawson County	485	1,258,119	2,594	74	17,151
Richland County	544	1,293,012	2,377	154	62,730
McKenzie County	574	1,064,191	1,854	49	19,913
River Corridor Counties Total	**6,303**	**15,232,307**	**2,416**	**2,326**	**457,531**
Source: United States Dept. of Agriculture (2012)					

Table 5-10
County Agricultural Statistics 1950

	Number of Farms	Land in farms (acres)	Ave. size of farm (acres)	Irrigated land (farms)	Irrigated land (acres)
Segment 1					
Park County	564	841,104	1,491	431	55,460
Segment 2					
Sweet Grass County	384	855,125	2,227	263	38,335
Stillwater County	647	901,132	1,393	314	28,305
Carbon County	998	652,287	654	787	80,847
Segment 3					
Yellowstone County	1,475	1,581,320	1,072	1,134	88,409
Segment 4					
Treasure County	163	483,326	2,965	97	11,405
Rosebud County	550	3,055,710	5,556	173	20,556
Custer County	506	2,412,808	4,768	254	25,541
Segment 5					
Prairie County	257	661,564	2,574	40	5,891
Dawson County	758	1,404,965	1,854	108	12,808
Richland County	1057	1,218,545	1,153	375	33,995
McKenzie County	1234	1,193,921	968	173	19,856
River Corridor Counties Total	8,593	15,261,807	1,776	4,149	421,408
Source: United States Dept. of Agriculture (1950 and 1949)*					

Throughout most of the river corridor counties, the majority of the land in farms is pastureland, ranging between 54.8 percent in Richland County and 91.9 percent in Custer County. The percentage of cropland ranges between 43 percent in Richland County and 6 percent in Custer County. Within the river corridor, the highest average per farm market value of machinery and equipment is in Treasure County (U.S. Department of Agriculture 2012). Aside from Custer, Treasure, Dawson and Prairie counties, the remaining counties within the river corridor received less revenue from agricultural property taxes as compared to their total property tax revenue (Montana Department of Revenue 2012). Yellowstone County produced the largest number of cattle and calves in 2012, as compared to other counties in the river corridor. Table 5-11 summarizes agricultural contribution by segment.

Current economic contributions of agriculture in the twelve-county area were estimated in IMPLAN using total output values for 19 agriculture-related sectors including grain farming, tree nut and fruit farming, animal production and commercial logging. Economic contribution analyses address the importance or contribution of an existing industry to a local economy.

Table 5-11
Agricultural Sector Impacts Summary

Segment & Impact Type	Contribution (in millions)		
	Employment	Labor Income	Value Added
Segment 1			
Direct	2,000	$37.6	$41.3
Secondary	200	$6.6	$15.8
*Total**	*2,200*	*$44.2*	*$57.1*
Segment 2			
Direct	2,600	$37.4	$56.3
Secondary	300	$7.0	$21.3
*Total**	*2,900*	*$44.4*	*$77.6*
Segment 3			
Direct	1,600	$28.9	$49.9
Secondary	500	$21.1	$42.6
*Total**	*2,100*	*$50.0*	*$92.5*
Segment 4			
Direct	4,200	$74.1	$97.0
Secondary	500	$17.6	$38.4
*Total**	*4,800*	*$91.6*	*$135.4*
Segment 5			
Direct	2,800	$84.8	$126.8
Secondary	600	$28.7	$62.8
*Total**	*3,500*	*$113.5*	*$189.6*

*Please note due to rounding, Total Effect reported may not be equal to the sum of Direct and Secondary Effects, as reported.

Table 5-11 summarizes the results of the contribution analysis. All results are presented in 2012 dollars. In 2012, agriculture in Segment 4, Treasure, Rosebud and Custer Counties, directly accounts for an estimated 4,200 jobs, $74.1 million in labor income, and $97.0 million in value added to the local economy. Secondary or multiplier effects of agriculture account for an additional estimated 500 jobs, $17.6 million in labor income, and $38.4 million in value added to the local economy. Accounting for both direct and secondary effects, agriculture in Segment 4 contributes an estimated total of 4,800 jobs, $91.6 million in labor income, and $135.4 million in value added to the local economy of the counties in Segment 4. Segment 4 has the highest number of jobs contributed by agriculture to the local economy in the River corridor. In 2012, agriculture in Segment 5, McKenzie, Richland, and Dawson counties, directly accounts for an estimated 2,800 jobs, $84.8 million in labor income, and $126.8 million in value added to the local economy. Secondary or multiplier effects of agriculture account for an additional estimated 600 jobs, $28.7 million in labor income, and $62.8 million in value added to the local economy. Accounting for both direct and secondary effects, agriculture in Segment 5 contributes an estimated total of 3,500 jobs, $113.5 million in labor income, and $189.6 million in value added to the local economy of the counties in Segment 5. Though agriculture contributes the greatest number of jobs in Segment 4, labor income and value added contributed by agriculture are highest in Segment 4. In Segments 1, 2, and 3, agricultural sector contributes to slightly above 2000 jobs in each. Contribution of labor income ranges between $44 and $50 million and value added ranges between $57 and $92 million in those segments.

5.5.3 Urban/Exurban Development

Much attention has been focused on urban and exurban development, defined as low density development of houses on 5 to 40 acres (Wildlife Conservation Society, Impacts of Low Density, Exurban Development). There is great concern over possible environmental damage and degradation that this type of development promotes (Vandenbosch and Erickson 2007). In 1996 and 1997 two floods along the Yellowstone River brought this discussion to the forefront. Many homeowners had developed their homes along the riverbank. In Park County, home loss due to flooding and the perceived risk led many remaining homeowners to apply to armor their river bank. Debate began over how far back from the river homeowners should develop their lots and what type of riparian damage this type of development was causing to the river's ecosystem. In 2007, a bill was brought to state legislation requiring, "new construction to be at least 250 feet from the high-water mark of a major river and provide a vegetative buffer at least 100 feet wide" (Vandenbosch and Erickson 2007). This bill did not pass, but the issues surrounding urban and exurban development continue to be analyzed and debated.

Yellowstone County accounted for over half of the total housing units, 63,943 units, while Treasure County had the fewest housing units, 422 units, in 2010. Carbon County had the highest percentage of housing units for seasonal or recreation use, with more than 1 of every 5 housing units used for seasonal or recreation use. In 2010, only 0.6 percent of the housing units in Yellowstone County are considered to be for seasonal or recreation use. Sweet Grass County had the highest homeowner and rental vacancy rates, 3.8 and 15.0 percent, respectively. Average household size remained fairly constant across the counties within the river corridor, with all households having an average size of less than three individuals (U.S. Census Bureau 2010).

Figure 5-2 highlights the change in developed land along the Yellowstone River 100-year floodplain from 1970 to 2008 by presenting the change in the number of homes over the period. The most extensive exurban developments have occurred in Park County and Yellowstone County (Billings area).

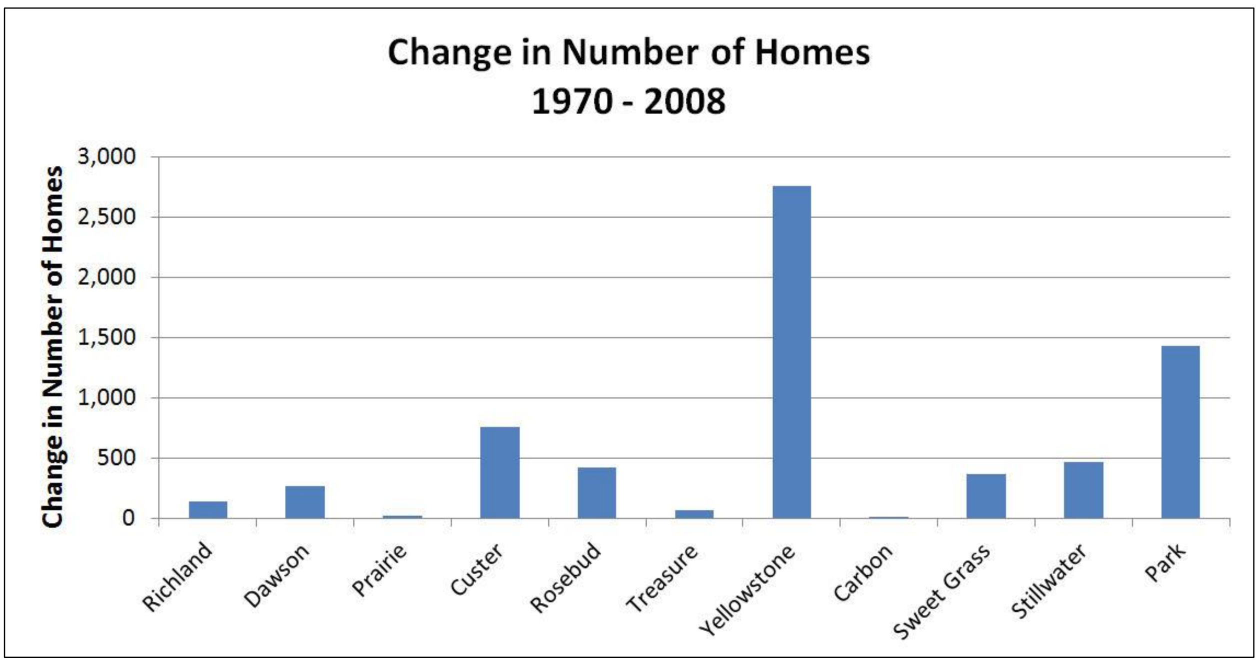


Figure 5-2 Change in number of homes from 1970 to 2008

The Billings area (Yellowstone County) has shown tremendous growth over the length of the study period within the inundation area. In 1950, urban and exurban uses were about 5 percent. By 2011, this had grown to between 20 and 32 percent, and both showed a continued steep upward growth curve. In Billings itself, the urban growth curve was even steeper, and urban/exurban development had grown from 25 percent of the inundation area in 1950 to 74 percent in 2011.

In Park County, conversion was primarily to exurban land uses, not urban. In Yellowstone County, urban development was primary. In Park County, that change in land use has occurred since the beginning date of the study of 1950. In 1950 there were only 39 acres of inundation area exurban development, and that acreage barely registers as a fraction of the total (i.e., 0.3 percent). By 1976, the trend of change in land use was well underway, having grown by a factor of 10, with 379 acres of exurban land-use conversion. That acreage had almost doubled again by 2001 at 652 acres and in the ten years to 2011 grew another 18 percent to 768 acres.

In Custer County, moderate increase in development has occurred at Miles City. In general, very little growth has occurred from Billings to the Missouri River junction between 1970 and 2008.

The counties within the river corridor as a whole received 28 percent of property tax revenue from residential property taxes. Park County is the only county that received over half of its property tax revenue from residential property, with 52 percent derived from residential property. Following Park County, Carbon, Yellowstone and Custer Counties received a third or more of their property tax revenue from residential properties, 41, 38 and 30 percent, respectively. For the remaining counties within the corridor, residential property taxes comprise less than 20 percent of county property tax revenue, with 5 percent of property tax revenue from residential property taxes in Prairie County, 2 percent in Rosebud County, and finally only 3 percent from residential property taxes in Treasure County (Montana Department of Revenue 2012).

Current economic contributions of the housing sectors were estimated in IMPLAN using total output values for two housing-related sectors, construction of new residential permanent sight single- and multi-family structures and construction of other new residential structures. These sectors include industries such as residential housing general contractors (i.e., new construction, remodeling, or renovating existing residential structures), operative builders and remodelers of residential structures, residential project construction management firms, and residential design-build firms. Economic contribution analyses address the importance or contribution of an existing industry to a local economy.

Table 5-12 and Table 5-13 summarize the results of the contribution analysis for housing across all five segments. All results are presented in 2012 dollars. In 2012, residential construction had the greatest contribution to Yellowstone County, Segment 3, with the construction of new residential permanent site single- and multi-family structures contributing 1,400 jobs and the construction of other new residential structures contributing 2,000 jobs, total. The construction of new residential permanent site single- and multi-family structures contributed over $100 million in labor income and value added in Segment 3. The two housing sectors contributed the least to Park County, with construction of new residential permanent site single- and multi-family structures and construction of other new residential structures contributing 110 and 170 total jobs, respectively.

Table 5-12
2012 Construction of New Residential Permanent Site Single- and Multi-family Structures: Sector Contribution Summary

Segment & Impact Type	Contribution (in millions)		
	Employment	Labor Income	Value Added
Segment 1			
Direct	70	$2.0	$2.8
Secondary	40	$1.2	$2.1
*Total**	*110*	*$3.3*	*$4.9*
Segment 2			
Direct	100	$3.1	$4.2
Secondary	60	$1.5	$2.7
*Total**	*160*	*$4.6*	*$6.9*
Segment 3			
Direct	600	$36.8	$43.6
Secondary	800	$31.6	$49.1
*Total**	*1,400*	*$68.4*	*$92.6*
Segment 4			
Direct	80	$4.1	$4.9
Secondary	60	$1.9	$3.2
*Total**	*140*	*$6.0*	*$8.2*
Segment 5			
Direct	200	$19.2	$24.6
Secondary	200	$6.9	$11.2
*Total**	*400*	*$26.1*	*$35.8*

**Note: Results are sum of contribution of construction of new residential permanent site single- and multi-family structures within each segment. See SocioEconomics Appendix for detailed results, segment numbering is opposite in the appendix.*

Table 5-13
Urban/Exurban Sector Impacts Summary

Segment & Impact Type	Employment	Contribution (in millions) Labor Income	Value Added
Segment 1			
Direct	110	$3.4	$3.7
Secondary	60	$1.7	$2.9
*Total**	*160*	*$5.1*	*$6.6*
Direct	400	$28.2	$28.2
Secondary	200	$9.2	$15.0
*Total**	*600*	*$37.4*	*$43.3*
Segment 2			
Direct	160	$5.3	$5.8
Secondary	80	$2.1	$3.8
*Total**	*240*	*$7.4*	*$9.6*
Segment 3			
Direct	1,000	$57.2	$60.3
Secondary	1,000	$43.9	$68.2
*Total**	*2,000*	*$101.0*	*$128.5*
Segment 4			
Direct	128	$6.2	$6.6
Secondary	84	$2.6	$4.5
*Total**	*212*	*$8.8*	*$11.1*
Segment 5			
Direct	400	$28.2	$28.2
Secondary	200	$9.2	$15.0
*Total**	*600*	*$37.4*	*$43.3*

**Note: Results are sum of contribution of construction of other new residential permanent structures within each segment. See Socioeconomics Appendix for detailed results, segment numbering is opposite in the appendix.*

5.6 Cultural Values Survey

The Yellowstone River Cultural Inventory—2006 (Gilbertz et al. 2006) was completed as part of the CEA. The following consists of excerpts from that report.

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. All participants were promised confidentiality; as such, no names or photos are included here.

Of greatest clarity across all groups is this notion: the Yellowstone River is the single, most important natural resource of southern and eastern Montana. Other conclusions can be drawn, but they can easily be challenged by evidence that demonstrates not everyone agrees. Moreover, general conclusions can simplify topics in ways that do not allow for nuances of understandings to be illuminated. Thus, even though the comments offered in this section are based on some overriding observations, they are not meant to serve as summations of how the people feel; rather, they are an attempt to offer resource managers some sense of the challenges that lay ahead.

5.6.1 Bank Stabilization

Along the course of the Yellowstone River, from the confluence with the Missouri River to Gardiner, Montana, riprap is a well-known method of bank stabilization. Across all interest groups, it is understood as a generally effective option for protecting property. Objections are raised by some, and alternatives are promoted by a few, but it appears that only one set of concerns keeps the majority of property owners from riprapping their riverbanks, the costs associated with riprap projects.

Put simply, the costs associated with materials and placements are viewed as prohibitive by many landowners. Stories of owners spending hundreds of thousands of dollars are commonly passed along as examples of why people have not riprapped their banks. Enthusiasms are sometimes diminished by knowledge gained from having watched the river "take what it wants," even when riprap was already in place. However, riprap is considered a worthy effort even by those who doubt its overall permanence as a solution.

Permitting processes are understood to be time-consuming and frustrating. More than a few property owners simply do not "want the hassle of dealing with so many agencies," and it is only those owners who hire someone else to deal with the design specifications and permitting details who are not overly offended by such requirements. Participants from all walks of life grasp the notion that pushing the problem onto your neighbor is not acceptable, but many people either implicitly or explicitly suggest that so long as one has enough money to pay for the appropriate "engineering," such issues can be resolved. While the permitting process is understood by many as a means of protecting neighbor from neighbor, it is seen as an impediment mostly working against the not-so-wealthy landowner.

Recreationalists discuss the need to avoid channelizing the river, but the cumulative effects of bank stabilization efforts are not topics that generate much conversation. Agriculturalists want to keep their productive lands, and residents, many of whom value the free-flowing character of the river, want to protect their homes. Given that real estate interests are certain to push for continued development of residential uses near the river, questions concerning cumulative effects are likely to be even more pertinent in the future. Park County serves as the example to the entire valley. After major flooding events in 1996 and 1997, the number of people willing to put resources in to riprap projects increased dramatically and that community has since gone through extensive public debates regarding bank stabilization methods and cumulative effects.

As a whole, the people of Park County are well-versed in explaining the arguments for, and against, the further use of riprap as a means of controlling the river. Unfortunately, Park County also illustrates that even though community members can become rather sophisticated in their abilities to discuss issues, they probably will not reach a consensus regarding the best courses of action. The prolonged discussions of the Park County Task Force demonstrate that when "best practices" are not the best option for each individual, consensus is probably impossible and voluntary adoptions are perhaps unlikely.

Many property owners accept limits designed to protect neighbor from neighbor. However, they are resentful of rules that appear to privilege the wealthy, require of them a less-than-effective means of protecting their personal property, or are constantly changing. Resources managers should anticipate that as more property owners feel compelled to control the river, either because they can afford to do so as preventative measures, or because they feel immediately threatened, pressures to approve bank stabilization projects will increase. Moreover, because management practices are likely to change over time, even at the local level, efforts to establish consensus agreements regarding such practices are likely to fail.

Efforts to engender wide-spread voluntary adoption of recommended management practices might succeed if individuals are convinced their personal interests are very well served, but resource managers must anticipate the objections that will be voiced and must generate the information needed to convince private owners that their interests will be served by the management practices being advocated at any given time.

5.6.2 Riparian Zone Understandings

Ideas about, and observations of, the riparian areas vary greatly. Surprisingly detailed inventories of animal life are offered by many as, apparently, people often keep journals of their observations. Some people record their observations on a daily basis and some as a matter of taking their annual river trip. Many are committed to “knowing” the particular birds, beavers, and even bears of their area. Residents, in particular, pay a great deal of attention to the wildlife and the seasonal migrations of birds and waterfowl. Agriculturalists and recreationalists, too, can offer extensive inventories of river animals. In these ways, the animals of the riparian areas are fairly well accounted.

With regard to the plants of the riparian areas, many people explain that they feel a great affection for the cottonwood trees. Many people are also aware of and concerned about invasive weeds. Agriculturalists and civic leaders seem to be the most informed. They speak of cottonwood trees as bank stabilizers and they identify specific noxious weeds and the strategies for dealing with them. However, knowledge across community members is not uniform, and people commonly complain about land owners who seem to be oblivious to the problems caused by lack of weed management. More than a few are disgusted by land owners who purposefully introduce Russian olive trees onto the riverbanks, and they are disheartened to see stands of weeds on river islands. In general, though, the plants of the riparian areas are seemingly less engaging than the wildlife. It was rare to find an individual with a journal chronicling the plant life of a given stretch of river, suggesting that plants are mostly taken for granted. For instance, only a few individuals express concerns regarding the age of the cottonwood stands.

It is only a few individuals in each geographic area that speak at length of the riparian areas as more than habitat for plant and animal life. For instance, only a few people explain that riparian areas can filter undesirable chemicals and nutrients out of run-off or irrigation discharge waters. Likewise, only a few explain that flood regimes are important to cottonwood tree regeneration. A few people discuss the impacts of grazing animals on riverbanks, but they seldom articulate in any detail the ecological impacts, positive or negative, of sediment transport processes. Least of all, individuals speak of hydrologic and geomorphologic processes as important to the health of the river. Those who have spent a great deal of time near the river are aware that the river is “constantly working,” and they rather vaguely explain that such workings are valuable in that they are natural. They offer few explanations of what those particular “natural” values might be. Attention to water quality is widespread, and many are concerned about the sewage contamination caused by inadequate treatment facilities, such as in Gardiner and on the tributaries.

The above observations suggest that much work is needed in educating the people of the river about the various functions of riparian areas. It seems that good riparian practices are currently, at best, a matter of attention to habitat. Specifically, it would be beneficial to help more people see the connections between wildlife abundance, clean water and healthy riparian functions. If more people were versed in explaining the linkages between wildlife, the physical processes, the plant life and the functions of the riparian areas, it seems many would be willing to protect those functions. As discussed above, voluntary adoption of recommended management practices must be attached to individuals’ self-interests. When they are convinced a particular practice is linked to their personal interests, vocational or vested, they are more likely to adopt it.

5.6.3 Managing a Shared Resource

The details of management concerns vary greatly across interest groups and across geographical segments; however, there is an obvious majority that regards management as essential to the long-term health of the river and its resources. Virtually everyone agrees that management of the river is complicated work. Their priorities vary according to their personal and vocational interests, but everyone knows they share the river with others and that not everyone will get everything they want when they want it. As tempting as it may have been to overstate their personal needs, it seems generally true that the people of the Yellowstone River promote balanced approaches as the most fair when managing the shared resources of the river.

One specific refrain comes through with great clarity when asked about how authorities should balance the needs of the various user groups. Namely, the people of the Yellowstone River believe in local control. Agriculturalists, local civic leaders, and residents all call for local control of the river's resources. They express a great deal of faith in local control as they view it as balanced control. They worry that state and federal authorities are not "in touch" with local needs, and many people, recreationalists included, view state and federal authorities as "slow to respond." Recreationalists are perhaps the most likely group to call on state and federal agencies to defend their interests. Yet, recreationalists are not without sympathies for local interests and are among the first to argue for a clear sense of balance in protecting the river's resources.

Some participants indicated that they could trust local officials not to meddle and not to forget the needs of the local community. It seems people are more willing to trust their neighbors to protect their interests. Perhaps they regard local control as essentially less rigorous.

Fortunately, even a brief review of the comments from local civic leaders convinces the most cynical reader that local leaders spend far too many hours listening to their various constituencies, and far too many hours juggling and sorting the many layers of local, state and federal guidelines, to allow a local focus to exclusively privilege any one group's interests. Local civic leaders are excellent examples. They sometimes feel trapped between local needs and official rules, but they are, indeed, dedicated to balanced approaches. Many locals, from all categories, understand their communities cannot afford detailed analyses of river issues, and they understand that other communities need similar types of information. Local civic leaders explain that good information is critical both in making decisions and in upholding unpopular rulings. They willingly admit that they depend on other entities to supply information, and they stress the need for an entity that can serve as a clearing house.

Thus, while many of the people of the Yellowstone River opt for local control, they want state and federal agencies to provide information and guidance. Members of all interest groups indicate that they would benefit from an organization that would gather, distill, organize and disseminate information that could be understood and put to use at the local level.

5.6.4 Specific Interest Group Findings Summaries

5.6.4.1 Agricultural Interest Group

There are five issues that seem to be most particular to riverfront agriculturalists. The first issue involves an apparent lack of effort, or success, by authorities and neighbors to eradicate noxious weeds. Saltcedar, leafy spurge, Canadian thistle, Russian olive, and spotted knapweed are all named as problems, and farmers and ranchers are unanimously concerned that their weed problems will only get worse. The second anxiety is related to the federal government's management of the floodplain. Many express fears about the creation of new regulations or restrictions on agricultural floodplain activity. Such regulations could affect the individual's productivity. The third concern is over the security of water rights. Changes in local and state demographic profiles are viewed with trepidation as agriculturalists fear that water adjudications could be affected. Fourth, agriculturalists often discuss the importance of storing water, especially as a means of keeping water for use in Montana. Finally, when taking all the issues into account, agriculturalists worry about the future of their livelihoods. At stake is far more than family incomes. Agriculturalists view the threats as potentially impacting their communities, their heritage, their culture and America's food supply.

It is apparent that the agricultural interest group views the various pressures on their livelihoods as real and threatening. It is also apparent that the agricultural interest group needs to develop new and more robust partnerships with agencies and other interest groups. Finally, it appears the Yellowstone Conservation District Council can play an important role in achieving constructive working relationships with the private agricultural producers that border the Yellowstone River.

5.6.4.2 Local Civic Leaders

There are several points of discussion that seem to carry great weight for individuals in local civic leadership roles. Conversations with these participants often include discussions about government and the philosophies behind democratic processes. They also discuss the challenges of local citizenries, the best ways to connect with state and federal entities and concerns about floodplain maps and official evaluations of local dikes.

Discussions with local civic leaders offer four implications for the future. First, there is a need to generate and share good information at the local level. Second, there is need to help local officials with the complexities of holistic management, especially new officials. Third, with limited resources and growing demands, it is obvious that not everyone will have everything they want. It seems certain that sharing the resources will only become more difficult. Finally, governance via rules and regulations will require multiple strategies and careful coordination across the various entities and agencies involved.

5.6.4.3 Recreational Interest Group

Three concerns seem to be at the heart of the recreationalists' perspective when considering the future of the river. First, they are dedicated to the uniqueness of the river, and are advocates of keeping the river free-flowing. Second, they view the public access laws of Montana as essential rights which must be protected against all threats. Third, they attend to water quality issues and are committed to encouraging best practices on the part of agriculture and industry.

Four implications emerge from an analysis of the conversations with recreationalists. The first is that recreational activities add a great deal to Montana's local economies. Many of the changes in Montana's communities are a result of the recreational appeal of the river. Second, recreational interests are linked, often legally, to the missions and purposes of governmental agencies; thus, recreationalists are likely to partner with any agency looking out for the health of the river. The third implication is that recreationalists are willing and ready to collaborate with agriculturalists in order to solve mutual problems. The fourth implication is that recreationalists worry about pollution and other effects of industrial, municipal and residential activities. However, they recognize their loyalties and interests are often ironically splintered, and so they ready themselves to accept the complexities and difficulties of working to address all interests.

5.6.4.4 Residential Interest Group

Residents are deeply committed to maintaining healthy wildlife populations and to high water quality standards. Yet, only a few of them are particularly well versed in explaining how the riparian areas contribute to each of these concerns. Rather, three different issues emerge as important when considering the residents' perspectives. First, they are especially protective of their property rights. They value their privacy. While they generally acknowledge the public's right to be on the river, they express varying degrees of understanding for recreationalists who violate the "high water" designations. They mostly oppose recreationalists using their properties as if they are public access sites. Second, when asked if they worry that they might be flooded or that the river might erode the bank away, there is a sizable group of residents who agree that over time such possibilities are real but who also explain away these threats by saying, "Not in My Lifetime/Years." These residents view the river as mostly benign and see no real threat to their properties. The third concern of residents is that they believe unchecked development near the river will eventually either ruin the privacies they have come to enjoy or force the sale of their homes as they will not be able to afford the subsequent increases in property taxes.

Four implications emerge from an analysis of the conversations with residents. The first is that residents are potentially strong allies when looking for individuals to support practices that will promote the health of the river and the riparian areas. However, at this point some are not well-enough informed to help. A second implication is that further residential development will decrease the informal paths that the public uses to access the river. Pressures will build for more public access sites. A third implication involves seemingly incompatible wishes. They appear to want a free-flowing river and the ability to protect private property. Given that the first wish is to some extent compromised every time the second wish is granted, it seems guidance is needed in the local communities regarding how to avoid further complicating matters with increasing riverfront developments. Finally, given that residents articulated so many different opinions and perspectives, it is apparent that every influx of new people and every new generation of adults will need to be educated and assisted in understanding the river, the management strategies, and the constraints of local governments.

5.6.4.5 Native Americans

There are three sets of concerns specific to Native Americans. They are concerned about pollution in the Yellowstone tributaries, especially as those problems are a function of faulty wastewater treatment facilities on the reservations. They are also concerned about the cultural separations occurring as each generation seems to be not only physically removed from the river, but spiritually removed as well. In some cases, these detachments from the Yellowstone River have caused tribes to relocate cultural practices onto the river's tributaries. The third set of concerns is articulated as vulnerabilities due to economic hardships and political problems that allow for unfortunate natural resource decisions.

Four implications are derived from discussions with Native Americans. The first is that the Yellowstone River should be managed according to holistic principles, those that include the entirety of the basin and its constituencies. Second, tribal communities should be given as much support as possible when dealing with problems that ultimately effect downstream water quality and quantity. Third, oral accounts of the river should be more fully gathered and incorporated into the official records of the river. And fourth, there are many mutually-beneficial opportunities for partnerships between the interests of the Native Americans, other interest groups, and managers.

6.0 CUMULATIVE EFFECTS ANALYSIS BY LAND USE

The previous chapters have highlighted numerous changes that have occurred within the Yellowstone River corridor since 1950, with some information available for changes prior to 1950. As data have allowed, the human activities associated with these changes have been identified. This chapter summarizes the human influences on the river corridor with respect to the three main land uses: agriculture, transportation, and urban/exurban development.

6.1 Effects of Agricultural Development

The most prominent land use in the Yellowstone River corridor is agriculture, which forms a strong foundation for the economy of the region. Agricultural development has included riparian clearing, irrigation infrastructure development, flow diversions, and bank armoring. Because of the spatial extent of agriculture, it has arguably had the largest overall effect on the physical and biological condition of the Yellowstone River. These effects include alterations in multiple components of the river system, including flow, aquatic and terrestrial wildlife habitat, floodplain/river connectivity, water quality, and rates of channel change.

6.1.1 Riparian Clearing

Although much of the area identified as agricultural is classified as multiple-use that includes grazing lands, there has also been substantial expansion of irrigated agriculture, which has necessitated riparian clearing. Extensive clearing occurred prior to 1950, and quantifying that early clearing is difficult. However, as much of the Yellowstone River woody riparian corridor lies within the historic 5-year floodplain, the amount of irrigated land in that footprint can approximate the minimum amount of riparian forest clearing that has occurred. This should be considered a minimum as the historic riparian corridor likely extended well beyond the 5-year floodplain.

Using the historic 5-year floodplain to coarsely approximate the historic minimum extent of the Yellowstone River riparian forest, at least 17,000 acres of forest have been cleared for irrigation development downstream of the Park/Sweet Grass county line (data not available for Park County). This translates to an average of 25 acres of riparian conversion per river mile. In these Regions (Regions A-D), a total of 2,400 acres of land in the historic 5-year floodplain has transitioned from open or closed timber to irrigated land between 1950 and 2001. Of those 2,400 acres, about 1,000 acres are in the existing 5-year floodplain, whereas 1,400 acres are in currently isolated floodplain area. In total, these data suggest that if the historic 5-year floodplain was supporting primarily woody riparian vegetation, about 14,600 acres of riparian forest had been converted to irrigated land by 1950, and another 2,400 acres since then.

6.1.2 Irrigation Infrastructure and Water Use

Water use in support of irrigation has included the construction of infrastructure in the river and within the floodplain, as well as the alteration in the timing and patterns of river flow.

All of the major diversion dams on the Yellowstone River were built by the mid-1930s. Most of these structures have fragmented aquatic habitat and affected fish passage.

Irrigation water withdrawals are the largest water use in the corridor, accounting for over 90 percent of the water used in the Yellowstone River counties and an estimated total of 3,012 million gallons per day or 4,660 cfs averaged over the entire year – when considering that irrigation primarily occurs during a four month period, the potential withdrawal is closer to 14,000 cfs. Approximately 75 percent of the irrigation withdrawals occur in the mainstem Yellowstone River and Clarks Fork. This water is not all consumed; an estimated 20 percent of the total withdrawals is consumed (Cannon and Johnson, 2004).

At Livingston, the effects of irrigation on overall flow regime are imperceptible, but by the mouth of the Clarks Fork, the results indicate an approximate 23 percent reduction in the summer 7Q10, which is the lowest 7-day flow expected to occur every 10 years during summer months. Below Laurel and the mouth of the Clarks Fork River, the influences of irrigation on Yellowstone River hydrology become more pronounced, indicating a measureable effect from irrigation in the Clarks Fork basin. Just below the mouth of the Clarks Fork River, the changes in flow statistics due to human influences include a 3,900 cfs or 7 percent drop in the 5-year flood flow, and a 4,200 cfs or 10 percent drop in the 2-year flood flow. At the Billings gage, summer baseflows are estimated to have dropped by 1,620 cfs or about 40 percent.

Water management in the Bighorn Basin has also contributed to the reduction in summer flows on the Yellowstone; at the Forsyth gage, for example, about half of the reduction in mean August flows can be attributed to Bighorn River flow alterations; the rest is attributable largely to irrigation.

6.1.3 Floodplain Isolation

The historic Yellowstone River 100-year floodplain has become isolated from flows due to the construction of dikes, levees, berms, roads, railroads, and floodplain grading/fill (see Section 4.4.3.2). Agriculture accounts for 17 percent of the total floodplain area that has been isolated (approximately 3,700 acres). The vast majority of this floodplain isolation due to agriculture has occurred in Region C, below Forsyth, predominantly from dikes and ditch embankments.

Floodplain isolation has also likely driven the expansion of irrigated agriculture. For example, isolation of the 5-year floodplain in Regions C and D, which is largely due to Bighorn River flow alterations, has been accompanied by the development of the majority of that area as irrigated agriculture. In total, over 17,000 acres of the historic 5-year floodplain are now in irrigated agricultural land use (Section 4.4.3.2).

6.1.4 Bank Armor

In Regions A through D, agricultural land uses are associated with approximately 46 percent of bank armor along the river (37 percent attributed to irrigated agriculture and 9 percent to non-irrigated agriculture; see Section 4.5.3.6). Bank armoring restricts channel migration by design. This in turn affects the rates of change for several ecologically important processes, including the turnover of floodplain habitats, recruitment of large wood, gravel bar development for native riparian regeneration, and formation of aquatic habitats.

Over the entire river corridor (Region PC through Region D), approximately one-third, or over 19,000 acres, of the erosion hazard area is in irrigated agricultural land uses, indicating a tendency for infrastructure investment in areas prone to erosion that may result in bank armoring.

6.1.5 Water Quality Effects

Agricultural land uses have the potential to degrade water quality. Several herbicides and pesticides have been detected in both surface and ground water in the study area (although at generally low concentrations), as well as increased levels of dissolved solids, sediment, and nutrients (compared to background levels) in the Bighorn River and Clarks Fork (Peterson et al. 2004). Irrigation return flows are a major source of suspended sediment as measured at Billings (Knapton and Balls 1993). Fertilizers and manure may contribute approximately 45 percent of the phosphorus load to the Clarks Fork (Smith et al. 1997). Nuisance levels of algae occur in segments of the Bighorn River and Clarks Fork (Peterson and Porter 2002). The water quality pollutants that are above MDEQ water quality criteria and most attributable to agricultural land uses include salinity, total dissolved solids, chlorides, suspended solids, ammonia, total nitrogen, and total phosphorus. Pesticides were only detected above state criteria in the lowest reach of the river.

6.1.6 Avian Habitat

As described above, agricultural land development has been the largest cause of riparian clearing in the corridor, and the vast majority of conversions of riparian habitats to agricultural land uses occurred prior to 1950 (Section 4.7.4). The total amount of direct riparian clearing since 1950 has been approximately 10 percent of the 1950s riparian area (nearly 7,000 acres), with the majority of this conversion to agricultural land uses (over 5,500 acres).

The effects of agricultural land uses on wildlife species (primarily birds in this study) result from three primary factors: (1) the decline in riparian habitat area, both natural forested and grassland areas, (2) loss of structural complexity in remaining riparian forested habitats, such as in heavily grazed areas and from reduced floodplain turnover, and (3) expansion of parasitic Brown-headed Cowbirds that flourish in association with livestock and exurban development.

Since 1950, the greatest extent of riparian clearing in support of agriculture occurred in Regions C and D, where the greatest numbers of riparian forest dependent bird species occur, particularly species of conservation concern. Although there has also been forest expansion into the historic channel area, rates of succession have gone down and the forest is at risk of aging with measured declines in young forest cover that will amplify the effects of riparian clearing on birds. Agriculture infrastructure (corrals, outbuildings, feeding areas) is strongly associated with the presence of Brown-headed Cowbirds which negatively impact populations of many riparian bird species, including several species of conservation concern. Most reaches have experienced an increase in the acreage of habitat impacted by cowbirds, with much of this increase attributed to agricultural expansion.

6.1.7 Fish Habitat

The impact of agricultural land uses on aquatic species includes the consequences of in-channel structures, water withdrawals, and reduced channel migration rates. Diversion dams can directly block fish passage and can entrain fish into the irrigation systems (Section 4.9.4.7). For example, adult Sauger mortality could potentially be reduced by 24 to 30 percent if entrainment into the irrigation systems was eliminated (Jaeger et al. 2005). Reduced peak flows resulting from agricultural impoundments and withdrawals reduce floodplain connectivity and formation of aquatic habitats (e.g., side channels, off-channel habitats). The intentional blockage of over 90 miles of side channels has likely reduced fish populations due to a loss of important habitat area. Although the land uses associated with side channel blockages have not been formally assessed, the majority of blocked side channels are in agricultural areas. Reduced low flows associated with irrigation water withdrawals may lead to increased water temperatures that encourage expansion of warmwater species to upstream reaches and reduced habitat quality and area for coldwater species. Elevated temperatures can also adversely affect some warmwater species such as pallid sturgeon.

6.2 Effects of Transportation Development

Considering its relatively small footprint on the landscape, transportation land uses have had a substantial effect on the Yellowstone River corridor due primarily to floodplain isolation and bank armoring. Most of the transportation infrastructure within the river corridor is relatively old; in 1950, about 664 acres of the Channel Migration Zone (CMZ) had been developed for transportation-related land use, and by 2011 that footprint had expanded to 800 acres total.

6.2.1 Floodplain Isolation and Bank Armor

The combination of all transportation land uses have contributed to 37 percent of the total mapped 100-year floodplain isolation (see Section 4.4.3.1). In Regions A and B, this isolation is primarily caused by Interstate-90; in Region C, the isolation is primarily caused by the railroad lines. Similarly, the transportation land uses account for 43 percent of the bank armoring along the corridor (nearly 41 miles), more than any other land use. This contributes greatly to a reduction of floodplain turnover, riparian recruitment, and accessibility of fish into refuge area during high flow events.

6.2.2 Water Quality Effects

Transportation land uses can degrade water quality from runoff of oils and greases, copper and zinc from brake linings and other vehicle components, sediment, and potentially catastrophic spills from railcars, trucks or pipelines. The Yellowstone River has experienced two significant pipeline ruptures since 2011, one in Region B near Billings and the other in Region D near Glendive.

6.2.3 Riparian and Aquatic Habitats

The direct conversion of riparian and wetland habitats to transportation corridors is limited due to the linear nature of the transportation network. The primary effect of transportation land uses on riparian and wetland habitats is the isolation of the floodplain and reduced channel migration. Both of these effects contribute to, first, an initial expansion of riparian vegetation into former aquatic habitats, and then a long-term decline as the cottonwood forest is not replaced from floodplain turnover. As the riparian vegetation ages and dies, it is replaced by more upland herbaceous and forest species. Similarly, as wetlands receive less water from the river and experience reduced turnover and formation of new wetlands, they will tend to transition to uplands. The isolation and drying out of riparian areas and wetlands also contributes to the invasion of invasive and non-native species that are more adapted to drier conditions and less flooding.

While direct impacts of transportation corridors on bird habitat are currently limited, the long-term decline in the extent of cottonwood forest habitat and wetlands is likely to affect species dependent on large expanses of forest. Other wildlife species are potentially affected when transportation corridors fragment migratory pathways, or when population suffer high rates of mortality due to collisions with vehicles and trains.

Transportation corridors negatively impact fish and other aquatic species by disconnecting off-channel habitats and reducing floodplain turnover, which in the long-term will reduce the area of off-channel aquatic habitats, such as side channels.

6.3 Effects of Urban/Exurban Development

Although urban and exurban land uses are a relatively small spatial component of the overall Yellowstone River corridor, around major communities they contribute substantially to bank armoring and reduced channel migration, and likely impact water quality. Continued residential development in the river corridor has generated some concern that the resulting impacts to overall river health will reduce the quality of life factors that have traditionally driven the development.

Urban and exurban development within the river corridor have expanded substantially since 1950. Within the CMZ, for example, about 850 acres of land was urban/exurban in 1950. By 2011 that footprint had expanded to 2,800 acres. The regions that have the most urban/exurban development within the CMZ are Region B which includes Billings (930 acres) and Region PC, which includes Livingston and the Paradise Valley (636 acres).

6.3.1 Floodplain Isolation and Bank Armoring

Urban levees associated with Forsyth, Miles City and Glendive isolate approximately 1,100 acres of the 100-year floodplain. At Billings, side channels have been blocked in support of urban/exurban development, resulting in a loss of several miles of side channel length since 1950. About 11 percent of the total amount of bank armoring in Regions A-D is attributed to urban and exurban land uses. As urban and exurban land use continues to expand, future increases in bank armoring are likely.

6.3.2 Water Quality Effects

Urban and exurban land uses can degrade water quality through municipal wastewater discharges, industrial discharges, septic discharges, and untreated stormwater runoff (see Section 4.6). Water quality has actually improved in recent years due to improved treatment requirements for both industrial and municipal waste discharges. However, many reaches of the Yellowstone River are listed as impaired waterbodies on Montana DEQ's 303(d) list (see Section 4.6.6). In the vicinity of Billings, low dissolved oxygen, eutrophication, and elevated levels of oil and grease, solids, nitrate/nitrite are all documented (State of Montana 2014). Regions B and PC are considered at greatest risk for water quality threats due to the density of septic systems.

6.3.3 Riparian and Aquatic Habitats

The direct effects of urban and exurban land uses on habitat are difficult to quantify with available data. Conversion of riparian habitats to urban and exurban land uses has been concentrated in the vicinity of Billings, Miles City, and Glendive (see Section 4.7.4). However, the majority of that conversion was from agricultural lands to urban and exurban land uses, so the original habitat was already altered. Bank armoring constructed to protect urban/exurban development reduces rates and extents of forest regeneration, and thus reduces habitat area for birds and other wildlife species. The isolation and conversion of riparian and wetland habitats will promote the spread of invasive non-native species that are able to survive better on land that is often disturbed and more intensively used. The isolation of floodplain wetlands behind levees and bank armoring also reduces their capability to provide functions such as flood attenuation and pollutant uptake.

Brown-headed Cowbirds, which negatively impact populations of many riparian bird species, are associated with urban and exurban development. Almost all of the cottonwood forest in the lower part of Region A and upper part of Region B (i.e., near Laurel and Billings) is impacted by cowbirds, mostly due to residential development in those reaches.

Water quality degradation can affect fish species through low dissolved oxygen (DO), higher water temperatures, and excessive growth of algae (that further reduces DO as it decays).

7.0 PRIMARY CUMULATIVE EFFECTS

The Yellowstone River is commonly referred to as “the longest free-flowing river in the lower 48 states.” This statement is true in that the mainstem has no major dams that are designed to impound large quantities of water. It does create the perception, however, that the river is minimally affected by human influences. The results of this study indicate that the Yellowstone River corridor has changed substantially from human influences over the last 150 years. Some of those changes may be considered beneficial with regard to reduction of risks associated with river corridor development. In general, however, the influences have resulted in a “taming” of river process. This change is seen as the transition of the Yellowstone River from a large, complex, and dynamic river corridor, to a river where, although physical and biological environments remain robust and dynamic, they have been demonstrably dampened relative to 150 years ago. Perhaps most importantly, study results indicate that the continuation of many of these activities may ultimately drive a wholesale transformation of the Yellowstone River to a highly impacted condition, one in which the processes that support river values highly desired by society become further impacted or even fully arrested.

This chapter summarizes cause and effect relationships identified on the Yellowstone River, with some expansion of that discussion into the likely cumulative effects. The evaluation of cumulative effects on a natural system is challenging due to the inherent complexity of interrelated cause and effect relationships. Because of the vast project area and the myriad of activities on the river, only those influences that have been identified as having a major effect have been evaluated in detail. These influences include hydrologic changes, land use changes, and construction of physical features on streambanks and in floodplain areas. The physical and biological responses to these influences include channel adjustments to altered flows, altered rates of channel movement due to bank armor, isolated side channel habitat, isolated floodplain area, and direct habitat alterations due to land development in the river corridor. Each of these responses then has secondary responses that can be considered in terms of water quality, avian habitat, fisheries habitat, and a range of other components of the river system.

This chapter first summarizes those cause and effect relationships that can be discerned from available data, and then expands that discussion to consider other likely consequences. This is then presented as a conceptual framework for likely cumulative effects, with supporting data presented where available. For example, data is available to quantify changes in hydrology on the river, but there are no complete datasets that characterize fish communities through time. As a result, the influence of hydrologic alterations on the Yellowstone River fishery must be to some extent be inferred from a basic understanding of fisheries biology and habitat preferences.

A primary objective of this discussion is to provide a framework that can help managers understand the nature of cumulative effects on river process, so that future responses associated with given actions can be anticipated and managed more carefully. This framework has been used to develop a series of recommended management practices for the Yellowstone River, which are presented in Chapter 8.

7.1 Altered Hydrology

Water storage and use for irrigation, flood control (i.e., Big Horn River reservoirs), and other uses have cumulatively altered the hydrology of the basin. The changes include both altered flow patterns due to reservoir storage on the Bighorn River, as well as reduced streamflow due to water withdrawals, primarily by irrigation. The river response to both reduced peak flows and reduced summer low flows is described below.

7.1.1 Reduced Peak Flows

Dams and irrigation withdrawals have reduced annual peak flows and flood flows. Figure 7-1 shows the estimated changes to peak flood flows along the river corridor (flows that occur with a probability of 50%, 10%, and 1% on an annual basis; commonly referred to as the 2-year, 10-year, and 100-year floods, respectively). The plot shows that in the upper river between Gardiner and the mouth of the Clarks Fork River near Laurel, the shift in flood flows has been on the order of a few percent, and this reduction in peak flows continues downstream to Bighorn due to the cumulative impact of irrigation. At the mouth of the Bighorn River at Bighorn, there is an abrupt increase in the impact; flows have dropped from about 16 percent (19,100 cfs) for the 100-year flood and about 23 percent (13,700 cfs) for the 2-year flood below the Bighorn River confluence at Hysham. The 100-year floodplain is an important indicator of overall floodplain extent, where floodplain areas can contribute diverse and important aquatic and terrestrial habitat. The 2-year flood, which is the typical spring runoff event, is an important geomorphic control, as rivers tend to adjust their size and form to accommodate that relatively frequent event.

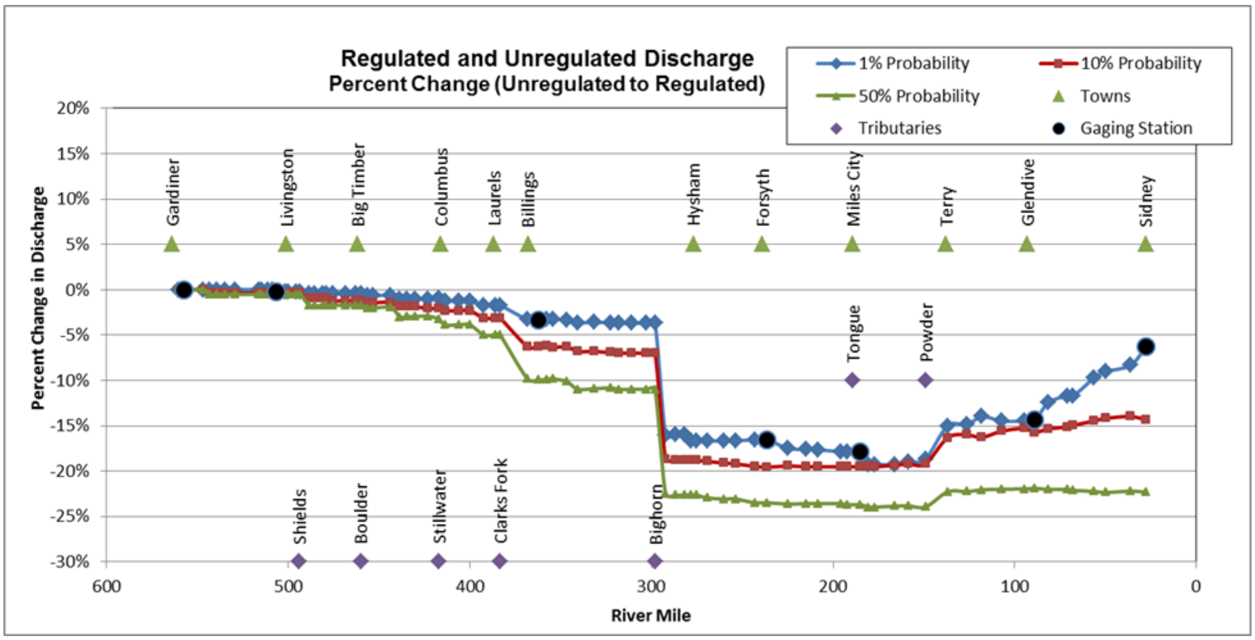


Figure 7-1 Percent change in 1-, 10-, and 50-percent annual exceedance probability discharge, regulated and unregulated conditions

Figure 7-2 shows a conceptual framework for the impact of peak flow reductions on the Yellowstone River. About 8,600 acres of total 100-year floodplain area has been identified as abandoned due to the reduced flows. Much of this isolation has occurred downstream of the Bighorn River confluence where the floodplain is especially broad and flat, which includes the corridor between Hysham and Miles City, and below Sidney. The consequences of this isolation include the direct loss of floodplain, riparian, and wetland habitats. Floodplain isolation also reduces flood risk in those areas, which in turn has promoted development in the historic floodplain. In the isolated 5-year floodplain, for example, there are 11,000 acres of developed irrigated land.

Another consequence of reduced peak flows is the reduction of the “channel forming discharge” (estimated by the 2-year flood), which has affected the size of the river channel, especially below Bighorn. An estimated 6,000 acres of riparian encroachment into old channel areas has occurred in response to the contraction of the channel footprint. This in turn has reduced the total area of channel habitat, perched side channels, and promoted an abrupt increase in riparian cover in these areas.

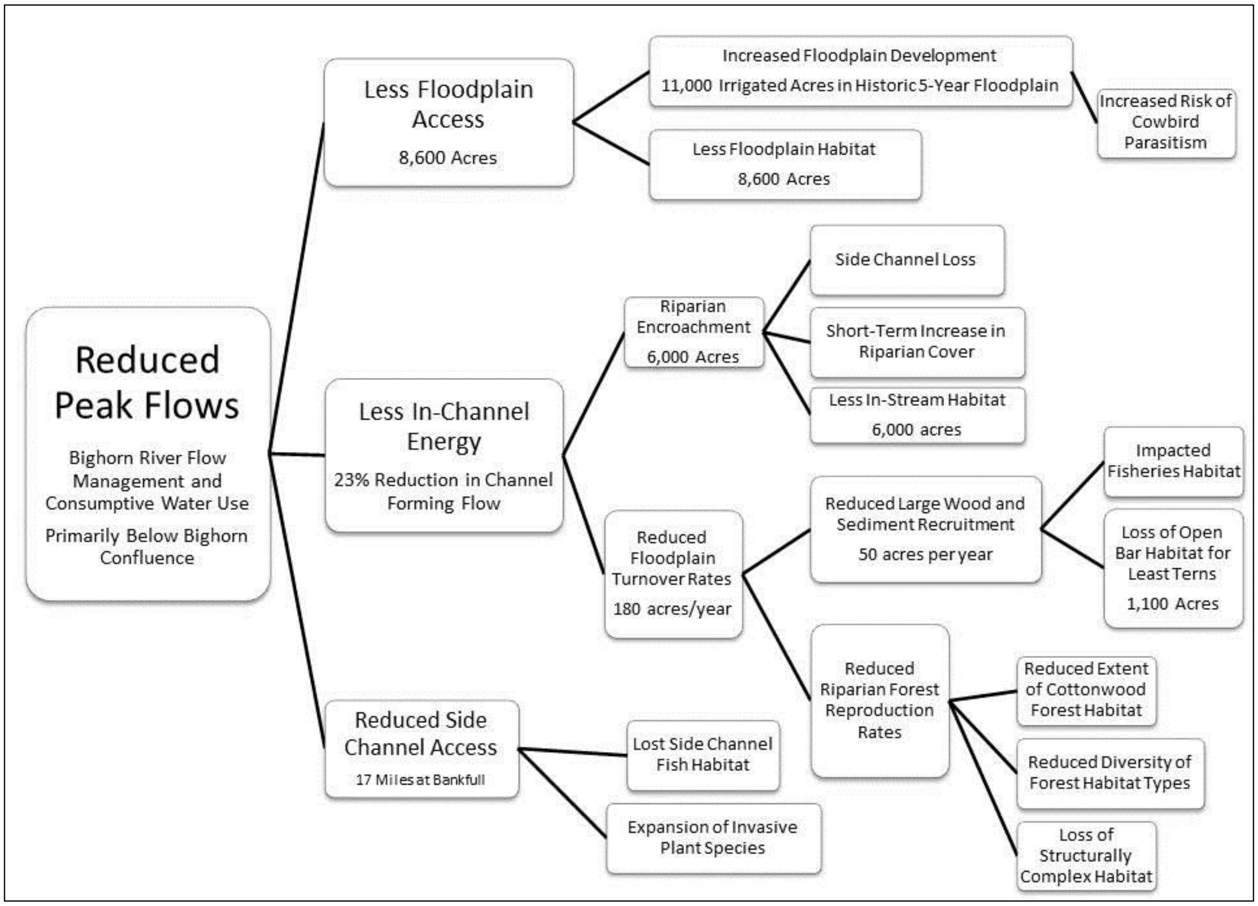


Figure 7-2 Schematic diagram showing cumulative effects from reduced peak flows

Reduced flows have also reduced the overall energy (stream power) in the river during a typical spring runoff event. This contributes to a reduced rate of bank erosion and floodplain turnover. An analysis of 60 years of channel movement indicates that on average, there are currently 180 acres less of floodplain erosion per year than historically. The reduced floodplain turnover rate on the Yellowstone River is measureable throughout the system, and the causes for this include both flow reductions and bank armoring, which is discussed in more detail later in this chapter. The consequences of reduced erosion and floodplain turnover rates reflect a general loss of the dynamism of the river, much of which has historically supported the creation and maintenance of both aquatic and riparian habitats. Floodplain erosion introduces trees to the river which contribute directly to fish habitat. An evaluation of erosion rates into riparian areas indicates that there has been a reduction of 50 acres per year of cottonwood forest eroded into the river since the 1950-1976 timeframe. Reduced turnover also reduces the rate of sediment recruitment and sediment transport, which, coupled with sediment trapping in reservoirs on the Bighorn River, has driven a decline in open bar habitat in the lower river. There has been a reduction of about 1,100 acres of mid-channel bar in the lower river since 1950; mid-channel bars surrounded by shallow water channels represent prime nesting and foraging habitat for Least Terns, while the low flow complexity provided by gravel bars and small channels also contributes to fish habitat complexity.

Perhaps one of the most striking consequences of reduced in-channel energy and dampened floodplain turnover rates is the reduction in rates of riparian forest reproduction. Cottonwood forests rely heavily on the creation of new open bar area for seedling establishment, and in river systems where rates of bank movement have substantially declined such that bars are not created, riparian communities tend to age without creating new young forest patches. In the short-term, this results in a loss of forest complexity due to the simplification of age classes, and in the long-term this can result in a massive loss of riparian forest due to a lack of regeneration.

Lastly, flow alterations have resulted in less frequent inundation of side channels, which provide important fish habitat. Russian olive mapping also shows that abandoned side channels are especially prone to invasive woody plant colonization and establishment.

It is important to note that in addition to the effects described above, less frequent inundation of the floodplain and reduced channel migration could encourage further development in the stream corridor. This development tends to encourage further bank stabilization which can amplify the effects described above.

7.1.2 Reduced Summer Low Flows

Water use and management has resulted in the reduction of summer low flows throughout the system. Typical summer low flows have been reduced at Billings from 4,000 cfs to approximately 2,000 cfs (nearly 50 percent reduction) and at Forsyth from 6,000 to approximately 3,000 (a similar nearly 50 percent reduction). Even in the uppermost part of the study area at Gardiner, research has indicated that August low flows have been lower over recent decades due to climate variability.

The conceptual schematic in Figure 7-3 shows a range of consequences of reduced summer flows. One of the largest concerns of low summer flows is the impact on fisheries due to changes in water temperature, habitat connectivity, habitat availability, and biological cues for movement. Low flows can also increase the risk of fish entrainment into pumps and canals.

Reduced summer low flows create challenges for various water users due to limited availability. In some cases, low flows require users to relocate or retrofit irrigation diversions and pumps and will often result in depressed crop yields.

Reduced low flows could lead to reduced recreational opportunities due to very shallow water depths and more concentrated pollutants, and the potential for increased nuisance algal blooms.

7.2 Floodplain Isolation by Physical Features

Section 4.4 describes the extent and consequences of floodplain isolation due to reduced peak flows. On the Yellowstone River there has also been substantial floodplain isolation due to physical blockages. These blockages include transportation embankments, floodplain dikes, and ditch berms that are associated with agricultural and urban/exurban land uses. Whereas about 8,600 acres of floodplain area has been estimated to be isolated due to flow alterations, approximately 13,000 additional acres are estimated to have been isolated by constructed floodplain features.

The conceptual diagram in Figure 7-4 shows some of the consequences of floodplain isolation by physical features. The reduced flood risk tends to promote agricultural or urban/exurban development in those areas, and may result in an increase in the abundance of cowbirds, which are associated with these land uses. These land uses have historically included riparian clearing that puts land at higher risk of expansion of woody invasive plants. Floodplain isolation also reduces the capacity of the river to naturally mitigate flooding by storing water and dissipating energy on the floodplain. And as floodplain soils are developed by the flooding process, their isolation from the river will result in long-term declines in productivity.

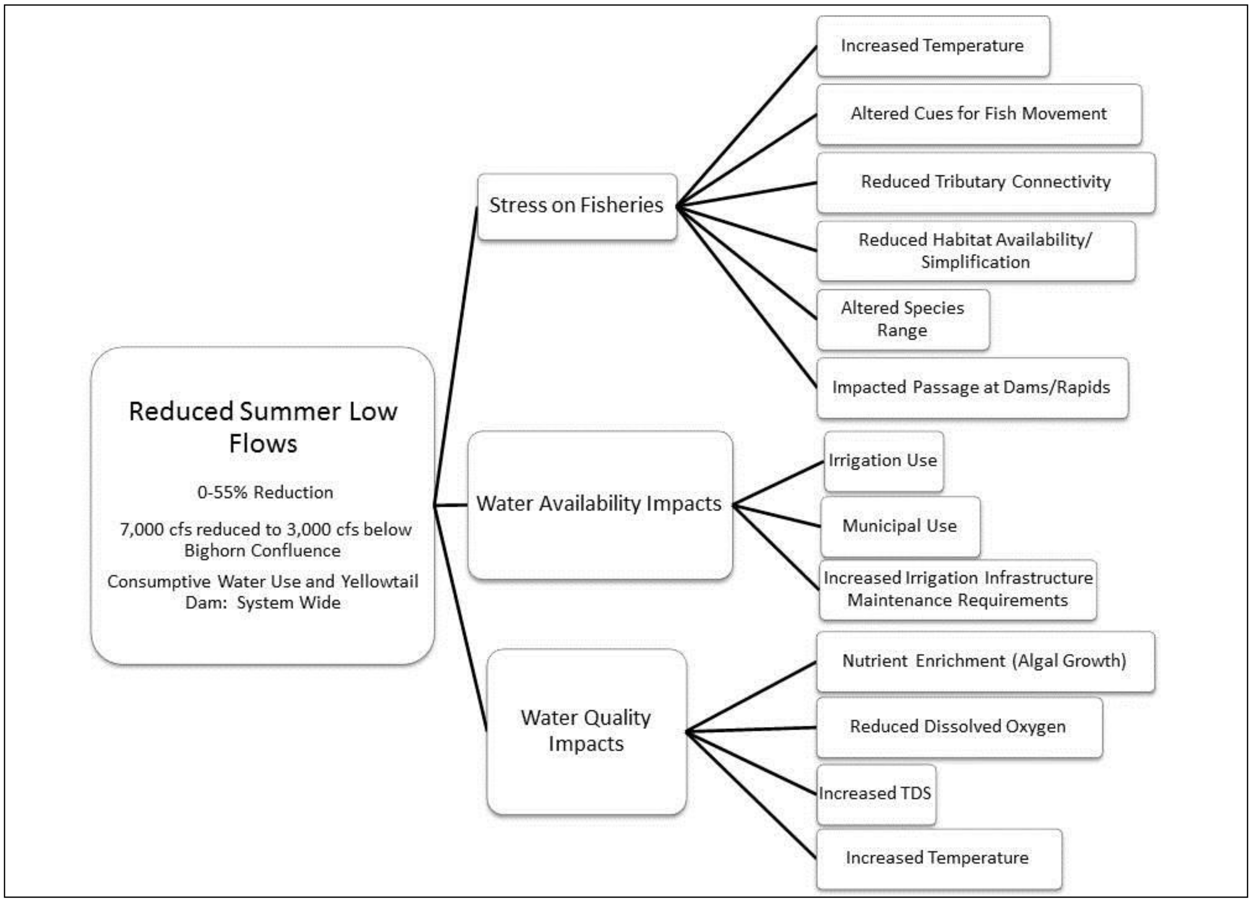


Figure 7-3 Schematic diagram showing cumulative effects from reduced summer low flows

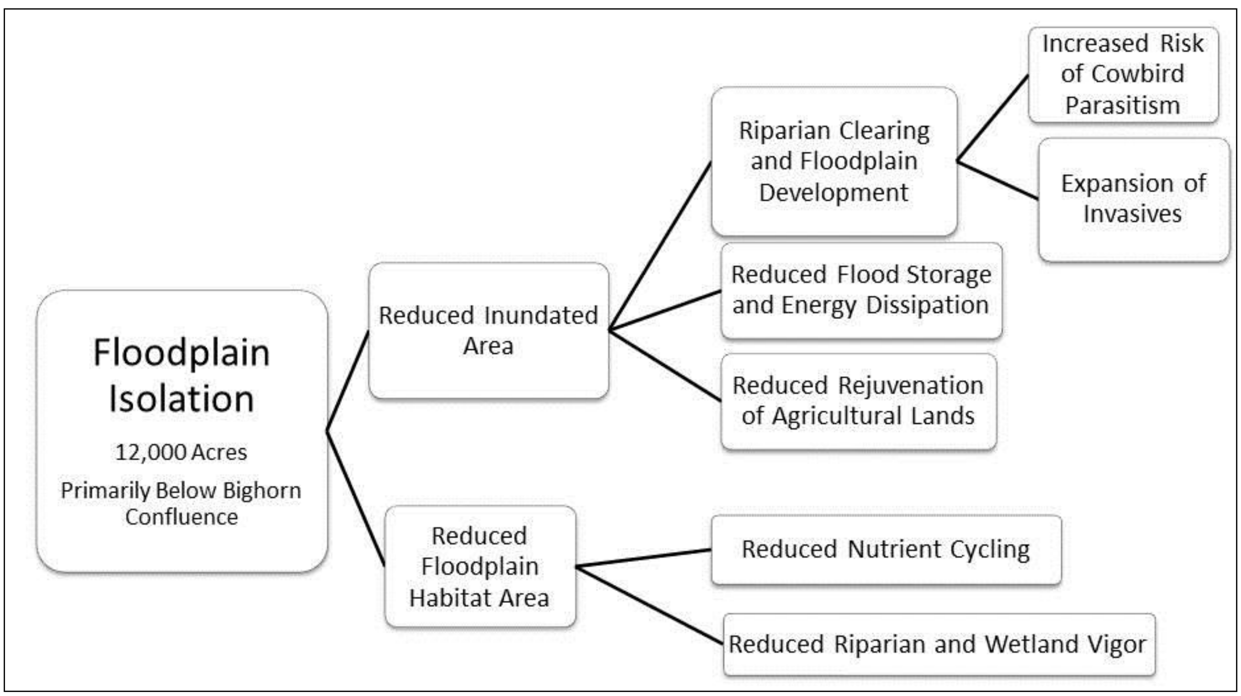


Figure 7-4 Cumulative effects Resulting from Isolation of the Floodplain

Another impact of floodplain isolation by physical features is the direct loss of that area as floodplain habitat. This will reduce the river/floodplain exchange rates, especially with respect to nutrients, potentially reducing the hydrologic connectivity and associated vigor of native riparian and wetland plant communities.

7.3 Land Development within the Channel Migration Zone

As described above, the isolation of floodplain areas in the Yellowstone River corridor has reduced the risk of flooding in those areas, which has in turn allowed expanded development on that historic floodplain. The impacts of floodplain development on off-channel environments are described above. Additional impacts of floodplain development occur when the development extends into the active river corridor where the risk of bank erosion and flooding is increased. The CMZ for the Yellowstone River identifies a 100-year migration corridor for the river that identifies those areas most prone to river erosion over the next century. Figure 7-5 shows the cumulative impacts of land development within the CMZ. Because of the proximity to the river, development within the CMZ has driven activities that have had a major cumulative effect on the system including riparian clearing, bank armoring, and blocking side channels. Bank armor and side channel blockages are described in later sections of this chapter.

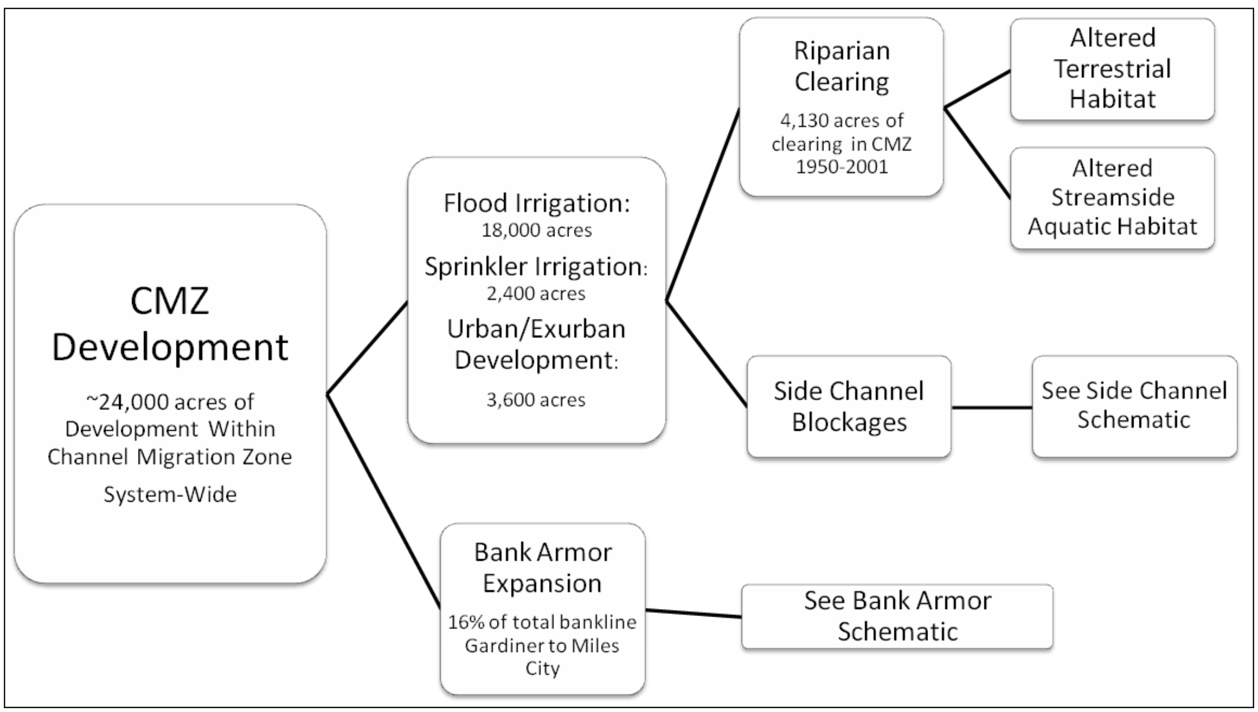


Figure 7-5 Schematic diagram showing cumulative effects of land development within the Channel Migration Zone.

About 4,130 acres of riparian forest has been cleared from the CMZ since 1950. Other disturbances associated with CMZ development can promote the colonization of woody invasive plants and noxious weeds that can reduce the productivity for grazing and affect terrestrial habitat.

Riparian clearing in the CMZ also affects fish habitat by reducing cover along the riverbank and reducing the recruitment of large wood (as there may not be any large trees to recruit). This reduces habitat complexity in the channel. While riparian shading is of lesser importance to a large river such as the Yellowstone, the lack of riparian tree canopy will allow more solar radiation to reach the water. This may increase water temperatures and promote the growth of algae and aquatic plants that may lead to reduced levels of dissolved oxygen when the plants decay on the bottom. The conversion to agricultural and urban/exurban land uses increases the volume of pollutants that enter the river via leaching into the shallow water table and from surface runoff during rainfall and snowmelt events.

7.4 Bank Armoring

One of the most spatially-extensive influences on the Yellowstone River channel is bank armor. As of 2011, there were approximately 136 miles of bank armor on the Yellowstone River below Gardiner, including rock riprap, flow deflectors, concrete riprap, car bodies, and minor extents of other techniques such as gabions and steel retaining walls. Rock riprap constitutes about 75 percent of the total armor. Between Gardiner and Miles City, about 16 percent of the bankline is armored, with less intensive bank protection below Miles City.

The expansion of armor on the river has been associated with river corridor development, as the typical intent of armor is to protect floodplain investments such as residential structures, transportation berms, irrigation infrastructure, and cropland. Bank armor was associated with adjacent land uses in Regions A through D. In the area between the Park/Sweet Grass county line and the mouth of the Yellowstone River about 37 percent of the armor was associated with irrigated agricultural lands, and another 36 percent with the railroad. About 11 percent of the bank armor in Regions A through D is associated with urban/exurban land uses. Figure 7-6 depicts the influences of bank armor observed on the Yellowstone River. The cumulative effects of armor can include both intended and unintended consequences.

The intended consequence of armor is reduced river migration rates and reduced rates of floodplain turnover. This has a very real effect on the Yellowstone River and has been described throughout this report. Data show that with bank armoring, river migration rates have been reduced. This has resulted in reduced rates of floodplain turnover and riparian regeneration, each of which then have effects on fisheries and avian/wildlife habitat. Effects include loss of habitat area and quality, reduced forest regeneration rates, and reduced recruitment of large wood and sediment from banklines.

In terms of unintended consequences, it is common for a stretch of bank armor to remain functional for a period of time, but to progressively develop a risk of failure as the river continues to migrate nearby. When armor starts to get flanked and erosion accelerates behind it, the project has to be maintained and typically extended to prevent complete failure. As a result, a bank treatment that is intended to be for a given length of bank commonly becomes unintentionally longer and longer through time, increasing its cumulative effect on the river. Another unintended consequence is complete armor failure, and failed bank armor creates a different type of effect. Between 2001 and 2011, at least four miles of bank armor were completely flanked on the Yellowstone River. This has resulted in the abandonment of bank armor material (large rock and concrete rubble) out in the channel. Flanked armor commonly causes dramatically accelerated erosion behind the rock structures, and creates navigational hazards. A third unintended consequence is broad scale channel downcutting. This process is extensive in the vicinity of Billings and is suspected of reaching a level of impact that has caused the perching of side channels. Downcutting may also have contributed to the recent exposure of pipelines in the channel bed near Laurel, which was followed by a rupture and oil spill. A fourth unintended consequence of armoring is the perpetuation of land development in naturally high risk areas due to the real or perceived risk reduction provided by the bank protection.

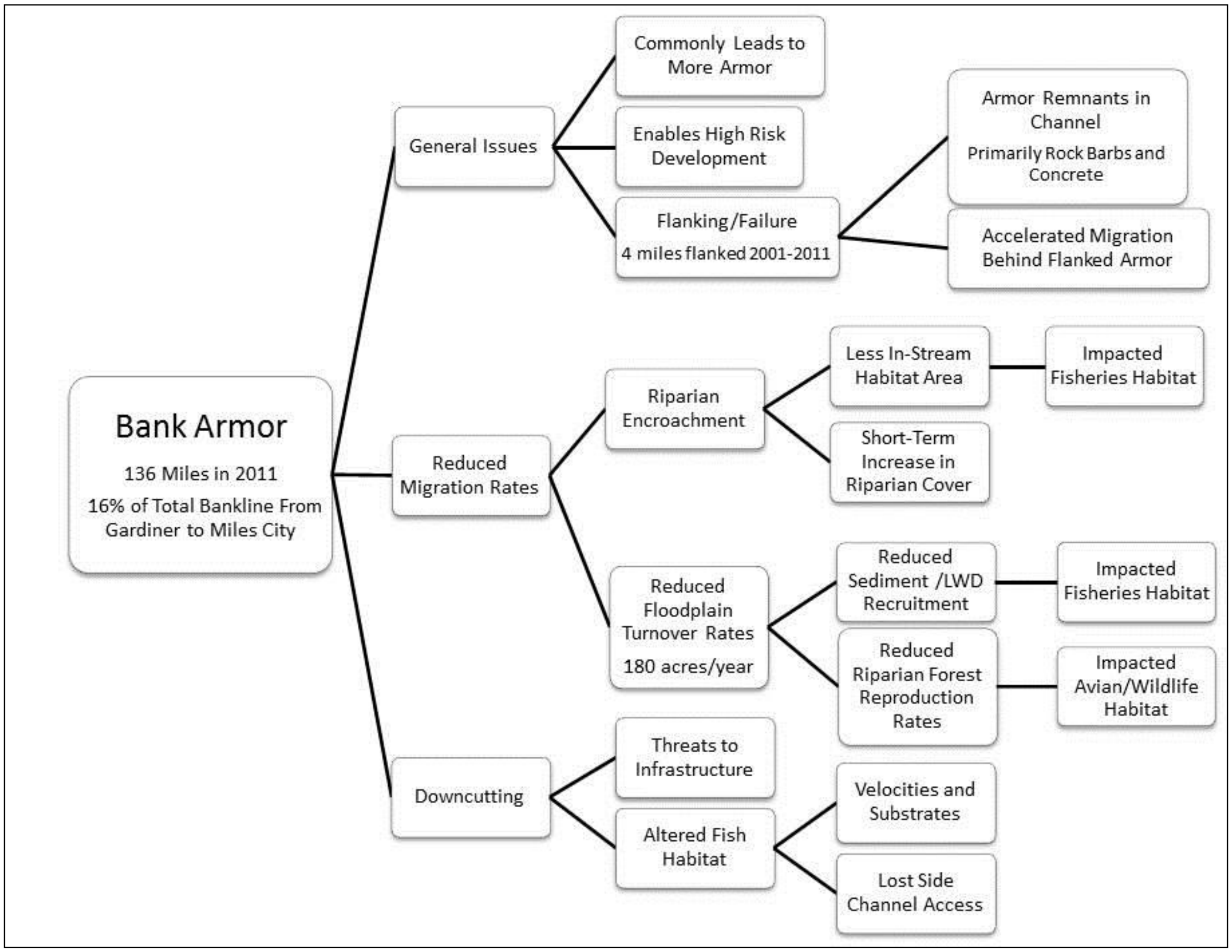


Figure 7-6 Schematic diagram showing cumulative effects of bank armoring.

7.5 Side Channel Blockages

Numerous small-scale floodplain dikes have cumulatively blocked approximately 89 miles of side channels on the Yellowstone River. About 42 miles of side channel had been blocked by 1950, and another 47 miles have been blocked since. The schematic drawing shown in Figure 7-7 depicts a range of consequences of those blockages. The most imminent concern for side channel blockages is the loss of important fish habitat. Side channel blockages result in the loss of total aquatic habitat area as well as the side channel-specific habitat type. Blockages are typically followed by expansion of Russian olive into those drier areas; there are about 650 acres of Russian olive mapped in areas that were active channels in 1950. As many of the blockages were created to increase access to agricultural lands, the process typically also includes bank armoring and riparian clearing.

Side channels can provide additional flow pathways during high flows and floods, thus reducing in-channel velocities and scour—essentially a relief valve for high flows. The isolation of side channels can lead to the confinement of flows within the primary channel and accelerated bank erosion and downcutting.

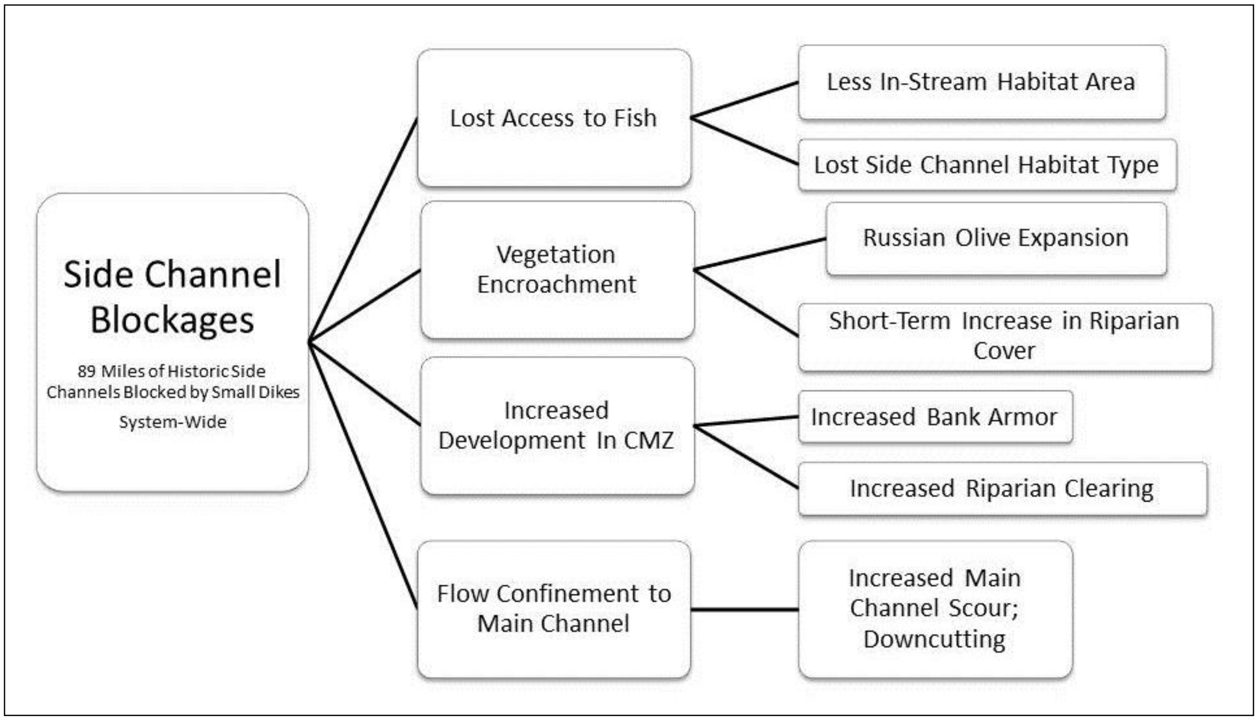


Figure 7-7 Cumulative Effects from Isolation of Side Channels (Blockages)

7.6 Altered Water Quality

Though the overall water quality in the Yellowstone River is good, however there are some noted impairments that are contributing to the cumulative degradation of water quality.

The Yellowstone River has numerous water quality impairments that are reflected in the 303(d) list (MDEQ 2015). The listings are prevalent throughout the study area and generally reflect nonpoint source runoff, such as from urban and exurban development and agricultural land uses. Municipal and industrial waste discharges contribute somewhat, but the nonpoint sources are likely the major driver of water quality degradation.

Higher water temperatures and lower dissolved oxygen concentrations can be harmful to fish and other aquatic species. Increased levels of nutrients can promote algal and aquatic plant growth that can further reduce dissolved oxygen when the plants decay and decompose. Suspended sediment and salts have been increasing from sources such as agricultural runoff. Metals such as copper, lead, zinc, and arsenic can be toxic to fish and other aquatic species and are both naturally present and contributed from urban and transportation land uses. Petroleum hydrocarbons and pesticides can also be toxic or bioaccumulate in fish and harm wildlife species as well. There is no evidence that current water quality conditions are having a substantial adverse effect on fish and wildlife populations, but if trends continue, then increased pollutants could harm species or promote changes to species distributions (for example, if warmer temperatures allowed warmwater fish species to expand further upstream).

Total dissolved solid (TDS) concentrations increase in a downstream direction through the watershed, likely as a result of nonpoint source runoff and reduced overall low flow volumes. Elevated levels of total dissolved solids are harmful to plants as well as aquatic life. While current levels are within recommended levels, potential increases in the lower river could drastically affect irrigation water that could lower crop production resulting in substantial economic impacts to irrigation water users.

Algal and plant growth can be of aesthetic and recreational concern, and also clog pumps and other water intakes. Several reaches are moderately impaired due to periphyton for contact recreation and aquatic life and fisheries. High levels of nutrients and bacteria can harm human recreational users and pets (e.g., fecal coliform). There can also be offensive odors as algae decays. Surface water withdrawals for drinking water could also require more substantial and costly treatment to ensure human safety for drinking water.

7.7 Invasive Species

Invasive plant and animal species represent another cumulative effect on the Yellowstone River corridor. Invasive plant species have been introduced both deliberately (pasture grasses and ornamental species) and unintentionally via birds and wildlife or seed drift from other areas. Of most concern for the Yellowstone River corridor are Russian olive and saltcedar. Both of these species can cause substantial effects to native riparian plant communities and cause geomorphic changes to the river itself through the dense growth of vegetation on bars and islands. At this time, approximately 4,600 acres of the 100-year floodplain are colonized by Russian olive (<1 percent). Saltcedar has less of a presence than Russian olive, but both species are likely to continue to spread unless management and control efforts are undertaken. Russian olive and saltcedar are more invasive on hydrologically controlled, less dynamic river systems (Lesica and Miles 2001). Dense stands of Russian olive and saltcedar crowd out other species and can chemically prevent other species from growing (e.g., concentration of salts around saltcedar) and create impediments to native wildlife species and livestock to access foraging areas. Native cottonwood forest has greater avian species richness than stands of Russian olive and saltcedar.

The expansion of Russian olive and saltcedar may result in the replacement of structurally complex cottonwood forest habitats with monotypic stands of Russian olive or saltcedar, which lack the large trees and dense canopy cover that many species depend upon.

Other noxious weeds that exist in the study area include spotted knapweed, Russian knapweed, leafy spurge, hounds' tongue, and Canada thistle. These species displace riparian communities and are a costly nuisance on agricultural lands.

In the coldwater zone of the river, introduced Rainbow and Brown Trout dominate the fishery and have contributed to the decline of the native Yellowstone Cutthroat Trout. Although most introduced fish species are relatively rare in the middle and lower river, the effect of introduced predators such as Smallmouth Bass, Walleye, and Northern Pike has not been studied. American bullfrogs are established in the river floodplain near Billings and have the potential to cause declines in native amphibians and reptiles.

7.8 Additional Habitat Alterations

Six large irrigation diversion dams (Huntley, Waco-Custer, Rancher's Ditch, Yellowstone Ditch, Cartersville and Intake) have impacted fish passage and habitat connectivity along the mainstem Yellowstone River. Although the degree of fragmentation of fish populations caused by these dams is not fully understood, they affect the distribution of and habitat availability for some fish species. Intake Diversion, which is the downstream-most structure on the river, is a major passage barrier that is currently the focus of efforts to provide passage for a range of fish species. The structure currently blocks passage by Pallid Sturgeon and Paddlefish under most flow conditions. Recent work has been completed to secure fish passage at Huntley Diversion as well.

In addition to creating fish passage barriers, irrigation withdrawals result in the entrainment of fish into ditches and canals. Although fish screens have been constructed at Intake Dam and at the T&Y dam on the Tongue River, entrainment is considered to be a major cause of fish mortality on the river.

Overall, the loss and alteration of riverine, riparian, wetland, and floodplain habitats will likely negatively impact fish, bird, and wildlife populations due to reductions in the availability of cottonwood forested habitat, loss of structurally complex habitat, and loss of shallow-water habitats. These effects occur across the entire study area.

The loss and alteration of riparian, wetland, and floodplain habitats may also contribute to increased erosion and channel migration (hay and crop lands are more easily eroded than forested areas), reduce the aesthetic and fishing/hunting values along the river, and water quality degradation will reduce the beneficial uses of the river (recreation, fishing, aesthetics).

8.0 RECOMMENDATIONS

The following recommendations have been developed to address major impacts identified in this CEA. These recommendations are presented in the form of Yellowstone River Recommended Practices (YRRPs), intended for individual land managers; or as Position Statements, more applicable to a broader range of stakeholders. They offer guidelines on developing land management strategies and locating structures within the river corridor.

YRRPs and Position Statements are the implementation component of the Yellowstone River CEA. They are recommendations that encourage long-term ecological sustainability of the Yellowstone River while preserving the economic viability of residents and communities who rely on the river. As circumstances, social norms, and technology change, the YRRPs and Position Statements will need to be periodically reviewed and updated to stay relevant.

Recommendations stemming from the YRRPs and Position Statements are briefly summarized in this chapter. For more detail and specificity, the YRRPs, Position Statements, implementation approaches, restoration project priorities, and future data collection needs can be found in the supplemental document: *Yellowstone River Recommendations – Practical Applications with a Cumulative Effects Perspective – 2015*.

8.1 Yellowstone River Recommended Practices (YRRPs)

The following recommended practices are summarized in this chapter:

1. Isolated Floodplain Restoration – Agricultural and Urban/Residential Development
2. Isolated Floodplain Restoration – Active/Abandoned Railroads and Public Roads
3. Side Channel Blockage Removal
4. Channel Bank Stabilization
5. Riparian and Wetlands Management
6. Invasive Woody Plant Control
7. Noxious Weed Control
8. Water Quality – Nutrient Reduction: Agricultural Land Use
9. Water Quality – Nutrient Reduction: Residential Development
10. Solid Waste Removal
11. Irrigation Water Management
12. Oil/Gas/Brine Water Pipeline Crossings
13. Altered Flows
14. Channel Migration Zone

15. Fish Passage and Entrainment

8.1.1 Floodplain Restoration - Agriculture and Urban/Residential Development

Since the late 1800s, an increasing amount of the Yellowstone River's historical floodplain can no longer be accessed by flood water. These traditionally flooded areas have become isolated for two reasons: constructed floodplain barriers (e.g., urban levees, dikes, elevated roads, irrigation ditches, railroad berms) and a reduction in high flows (tributary storage reservoirs and irrigation withdrawals). Nearly 5,000 acres of the historical 100-year floodplain has been lost due to dikes and levees associated with agriculture and urban/residential development (Section 4.4.3.1).

Restoring and maintaining the connection between the floodplain and the river's active channel is critical. Values associated with a functional floodplain include flood energy dissipation, water storage, agricultural land rejuvenation, water quality filtration, and riparian habitat sustainability.

This YRRP provides general guidelines for the removal or modification of physical dikes and berms on the Yellowstone River 100-year floodplain that are associated with agricultural and urban/residential land uses.

- ***Old and Abandoned Structures:*** Remove old structures located on the 100-year floodplain that are no longer functional or in use. These structures may include abandoned buildings, irrigation infrastructure, elevated ditches, solid waste dumps, farm roads, etc. Non-earthen material (wood, steel, tin, garbage) should be disposed of outside the 100-year floodplain in an approved landfill or recycling center. Once the structure is removed, the site should be graded back to the normal floodplain elevation. All disturbances should be vegetated with species compatible with surrounding land uses.

- ***New and Existing Structures:*** New structures should be located outside the 100-year floodplain. When this is not possible, the structure should be designed and sited to minimize its footprint on the floodplain. Existing structures that are significant floodplain obstacles or barriers should be relocated or modified to minimize their impacts on the floodplain.

- **Elevated Roads:** For an elevated private road, modifications can be made to allow a controlled amount of flood water passage. Road modification designs must consider the road's primary purpose, frequency of use, adjacent land uses, drainage patterns, flood water entry/departure points, and the most effective method to pass flood waters through the road berm (e.g., bridges, culverts, hardened swales). Flood by-pass structures should be designed to pass floodwaters as shallow sheet-flow rather than a concentrated channelized flow that could erode new gullies across the floodplain. A stable path for floodwaters to return back to the river should also be part of the project design.

- ***Agricultural Berms:*** Agricultural berms include elevated irrigation ditches, field dikes, and farm roads. These berms not only restrict the spread of floodwaters, but will often catch or collect floating debris that piles up on fields and pastures. Larger floods will sometimes overtop or breach these berms resulting in concentrated flows that may erode deep rills and gullies across the fields.
    - **Restoration Approach:** If an agricultural berm has outlived its purpose, total or partial removal of the berm should be considered. The berm should be graded back to the original floodplain elevation with the excess berm material either transported out of the floodplain or thinly spread on-site. For berms still in use, modifications can be made to pass floodwaters and to effectively move floating debris. Any proposed design would need to consider the same criteria outlined above for elevated roads.

- **Urban Areas and Exurban Residential Tracts**: There are urban areas and rural residential developments on the Yellowstone River where dikes and levees were built to protect homes and property from flooding . As these dikes and levees age, the costs for repair and reconstruction can be extremely high. In these situations, it may be impractical or unpopular to fully reconnect the historical floodplain to the river; however, measures to reduce their impacts are possible.

- **Existing Levees:** When existing levees are being repaired or rebuilt, they should be set back away from the river to the extent possible. In addition, the inclusion of fail-resistant spillways should be incorporated into the levees so that when the levee design is exceeded, excess flow passes through the spillway preventing catastrophic overtopping or failure of the structure.

- **New Levees:** New levees should be built as a last resort and only after other measures, especially nonstructural ones, have been fully considered. Levees should never be used as a means to facilitate the development of currently undeveloped flood-prone lands.

Figure 8-1 Gravel dike on the floodplain near Billings, built to protect a residential development from flooding

8.1.2 Isolated Floodplain Restoration - Active/Abandoned Railroads and Public Roads

Transportation infrastructure (public roads and railroads combined) has a relatively small footprint on the 100-year Yellowstone River floodplain (approximately 3 percent). Even so, transportation corridors in the Yellowstone River Valley have contributed to 37 percent of the total floodplain isolation.

The active railroad grade (MRL and BNSF) intermittently crosses the historical Yellowstone River 100-year floodplain for a total of 102 miles, isolating over 3,500 acres of floodplain. The abandoned Milwaukee Railroad intersects the floodplain for a total of 25 miles leaving 2,300 acres of historical floodplain inaccessible to floods (Section 4.4.3.1).

Public highways and county roads are more flexible in their design and location and encroach less upon the river's floodplain than that of the railroads. They are responsible for 2,050 acres of isolated floodplain (Section 4.4.3.1). Most public roads in the floodplain are two-lane highways or county roads. The Interstate Highways 90 and 94, completed in the 1970s, make up nearly 415 miles of roadway in the Yellowstone River Valley, however they have a relatively small effect on the floodplain because they are located primarily on the periphery of the river valley.

This YRRP addresses the impacts that railroad and public road berms have on the Yellowstone River 100-year floodplain.

- ***Active Railroads:*** Opportunities to reconnect the historical floodplain that has been isolated by the active railroad grade may be limited. More practical restoration options may exist with tributary connectivity and grade stabilization.
    - **Tributary Connectivity and Grade Stability:** Establishing tributary connectivity to the Yellowstone River would allow for fish passage, reclaim land lost from ponding or salinization, and minimize saturation and slumping of the railroad grade. Culverts, pipes, concrete boxes, or small bridges should be installed through the railroad grade to pass run-off flows from perennial, intermittent, and ephemeral side drainages. These by-pass conduits should be sized to accommodate a 100-year frequency flow to prevent ponding and backwater against the upslope side of the grade and be designed for fish passage. Discharges through the railroad berm will require a stable waterway to the river.
- ***Abandoned Railroad - Milwaukee:*** The Milwaukee railroad grade has been abandoned since 1980 (
- Figure **8-2**). Since it is no longer maintained, it has become increasingly vulnerable to unchecked bank erosion and berm failure that could have severe consequences to property once protected by the old grade. The potential exists for restoring the historical floodplain behind the Milwaukee Railroad at some locations. A systematic evaluation of the old railroad fill should be completed to identify possible projects for flood by-pass structures, strategic breaching points, and/or full grade removal.
- ***Public Highways and County Roads:*** Most public highways and county roads are either located outside the 100-year floodplain or are buffered by other floodplain berms, often the railroad grade. There may be opportunities to install or enlarge flood by-pass structures on some public roads that would better accommodate side drainage runoff going to the Yellowstone River and flood waters spreading out from the river.
- ***Bridges:*** Over 50 highway and railroad bridges cross the Yellowstone River. Most are public bridges. The only private bridges are those owned by the railroad.

- **Active Bridge Crossings:** All future bridge construction or replacement should incorporate zero backwater design standards (span, piers, and abutments) to minimize upstream gravel deposition and downstream channel scour. Design standards should assure a bridge capacity that can readily pass 100-year flood events and not exacerbate localized ice jams.

- **Abandoned Bridge Crossings:** For bridge crossings no longer in use, restoration projects should be initiated to remove old bridge abutments and piers, and to grade bridge approaches back to the original floodplain elevation.

Figure 8-2 The abandoned Milwaukee Railroad grade crosses the historic floodplain west of Miles City

8.1.3 Side Channel Blockage Removal

Side channels located in the floodplain provide important habitat for fish, amphibians, reptiles, birds, and other aquatic organisms. Side channels tend to be shallower with slower current velocities, more habitat diversity, and higher productivity (fish recruitment and food sources) when compared to the main channel (Section 4.9.4). Keeping side channels open also helps disperse high flow energy resulting in less bank erosion, channel scour, and flood damage along the main river channel.

The loss of side channels is caused either by physical blockage and/or the reduction in high flows (Figure 8-3). Because of the altered flows, the duration of side channel inundation during high flow events is less. Between Gardiner and the Missouri River confluence, 42 miles of side channels had been physically blocked on the mainstem Yellowstone River prior to 1950. An additional 47 miles were blocked between 1950 and 2001 (Section 4.5.3.1). This YRRP provides general guidelines for the removal or modification of physical blockages that will benefit aquatic habitat and provide flood relief.

- **Total Blockage Removal:** Completely removing a side channel blockage to restore high water flow access is the best alternative when restoring side channel function and value. The pros and cons of implementing complete removal should be considered early on in the planning process.

- **Water Control Structure:** Where blockage removal presents too high a risk (flooding, river capture, bank destabilization), retrofitting or replacing the physical blockage with a water control structure (e.g., culvert, bridge, constructed overflow channel, etc.) to regulate high flow access and provide fish passage to a side channel is a viable option. This alternative may not provide full functionality to the side channel, but it would restore some level of aquatic habitat.

- **Side Channel Restoration:** Restoration work to the channel is often necessary in addition to modifying or removing the side channel blockages. This may include excavating accumulated sediment from the side channel, channel shaping, grade control to prevent river capture, removing invasive species that have encroached on the channel, and constructing fish habitat (pools, spawning substrate, woody cover, etc.) that is conducive to the local fisheries or possibly to a targeted species.

- **Adjacent Land Planning:** For reactivated side channels, flood hazard remediation may be necessary to address increased flooding potential on fields and infrastructure next to or downgradient of the side channel. Remediation could be in the form of vegetative buffers, structure relocation or floodplain easements.

- **Maintaining Existing Side Channels:** For side channels currently connected to the river, maintaining their function as aquatic habitat and flood relief should be an important objective in long-term land management planning.

Figure 8-3 Blocked side channel west of Big Timber

8.1.4 Channel Bank Stabilization

The Yellowstone River is a naturally meandering stream causing banks to erode and channels to shift. In winter, ice can be another major factor affecting bank erosion. Eroding river banks are not necessarily bad and don't always need to be "repaired." In fact, bank treatments that lock the river channel in place will impact the river by restricting riparian forest renewal, degrading fisheries habitat, and lessening the river's ability to adjust to fluctuating flows and bedload.

As of 2011, there are approximately 136 miles of bank armor on the Yellowstone River from Gardiner to the Missouri River. This is equivalent to 12 percent of the Yellowstone River (main channel plus active side channels). The primary land uses protected by bank armor are agriculture-related (irrigated lands and infrastructure) at 37 percent and railroad rights-of-way at 36 percent. The remaining land uses with bank armor include urban/exurban, 11 percent; non-irrigated lands, 9 percent; and public roads, 7 percent (Section 4.5.3.6).

The most common type of bank armor is rock riprap at 75 percent. Concrete riprap (Figure 8-4) and flow deflectors account for 23 percent. Car bodies, gabions, steel retaining walls, and soft bioengineering make up the remainder at 2 percent (Section 4.5.3.6).

Figure 8-4 Concrete blocks dumped on the riverbank are ineffective and will likely accelerate the rate of bank erosion, rather than prevent it

Channel Migration Zone (CMZ) Maps: CMZ maps define areas along the Yellowstone River that are prone to bank erosion over the next 100 years. CMZ map boundaries are based upon geologic mapping and measured rates of lateral channel change derived from fifty years of historical aerial photography. CMZ maps are an important tool for decision-makers that will lessen the risk of infrastructure failure and minimize the necessity for expensive bank armoring.

- **Structures – Channel Migration Zone:** The reason that most landowners and state/local government invest in bank armor is to protect high-value structures (e.g., houses, outbuildings, irrigation sprinklers, roads) being threatened by the river. Since bank armor is costly to maintain and often subject to failure, locating new structures and relocating old structures outside the 100-year CMZ is the best long-term option.

- **Agricultural Lands**

  - **Cost/Benefit:** For cropland, riparian forest, pastureland, etc. being threatened by river migration and bank erosion, the 100-year CMZ map predicts the amount of land that could potentially be lost. This acreage estimate provides information to determine economic costs/benefits comparing property values and long-term production losses with bank armor installation and maintenance expenses. The expense of bank armor required to adequately protect cropland is often not economically justified.

  - **Flood Irrigation – Bank Saturation:** Irrigation ditches and flood irrigated fields located too close to the river will often saturate the river bank. Saturation will weaken the river bank making it vulnerable to sloughing and accelerated erosion. This can then lead to expensive bank armor that ends up addressing the symptom rather than the actual problem. There are several options to address bank saturation depending upon landowner objectives and site conditions:

    - Relocate irrigation ditches away from the river channel
    - Line irrigation ditches or replace with buried pipelines to reduce seepage
    - Develop a flood irrigation tailwater system that transports waste water efficiently off the field
    - Convert to sprinkler irrigation that reduces excessive soil saturation and waste water run-off
    - Plant a vegetative buffer between the river and irrigation field, ideally the width of the 100-year CMZ. The buffer would be planted with deep-rooted native plants.

  - **Sprinkler Irrigation:** New sprinkler systems should be located outside the 100-year CMZ to avoid the expense of either installing bank armor or relocating the on-farm sprinkler system in the future. For existing system upgrades, reorienting fields and locating sprinkler pivot points/pipelines outside the CMZ would lessen the need for future bank armor.

- **Channel Migration Zone (CMZ) Easements:** CMZ easements may be an alternative to bank armoring in that they maintain the river's ability to migrate while offering opportunities to landowners to realize return on their land. The CMZ easement programs are in their infancy so available funding may not meet the demand over the next few years. Inquire with your local Conservation District on CMZ easement opportunities.

- **Failed Bank Armor Removal:** Failed bank armor and flanked flow deflectors sometimes end up as rubble in the active river channel. This rubble will often deflect the current into the bank, thereby accelerating bank erosion that it was originally intended to stop. It also creates a safety hazard for boaters and recreationists and a potential liability for landowners. Failed bank armoring and flow deflectors should be removed from the active channel. The material should then be either reused or transported off-site.

- **Bank Stabilization Guidelines:** Where existing high value property cannot be relocated and bank armoring is the only viable option, the supplemental document *Yellowstone River Recommendations – Practical Applications with a Cumulative Effects Perspective – 2015* provides design criteria for the most common types of bank armor used on the Yellowstone River: rock riprap, concrete riprap, and flow deflectors.

8.1.5 Riparian/Wetlands Management

Riparian forests and wetlands are common along the Yellowstone River channel and throughout the adjacent floodplain. They are distinctly different from the upland landscape because of their unique soil and vegetative characteristics, strongly influenced by a high ground water table and periodic flooding. The loss and alteration of riparian and wetland habitats has been identified as a substantial cumulative effect on the Yellowstone River Corridor.

Early records and historical documents indicate that the pre-settlement Yellowstone River Corridor supported abundant stands of cottonwood and other native species. Much of this had been harvested or cleared and converted to other land uses prior to 1950. As of 2001, approximately 21 percent of the 100-year floodplain remains in riparian forest. In addition, about 20,000 acres of riparian vegetation has been isolated from the 100-year floodplain due to reduced peak flows and constructed barriers such as dikes, roads, railroad grades, etc. (Section 4.7.3). Throughout the river corridor, noxious weeds and invasive woody plants are increasingly crowding out native vegetation.

This YRRP includes guidelines for restoring or maintaining healthy riparian forests and wetlands along the Yellowstone River Corridor.

- **Floodplain Restoration:** Since the late 1800s, an increasing amount of the Yellowstone River's historical riparian forest is no longer accessed by flood water. These traditionally flooded areas have become isolated for two reasons: constructed floodplain barriers (e.g., urban levees, dikes, elevated roads, irrigation ditches, railroad berms, etc.) and a reduction in high flows (tributary storage reservoirs and irrigation withdrawals). Refer to Sections 8.1.1 and 8.1.2 for guidelines on removing or modifying floodplain barriers.

- **Agriculture:** Site-specific grazing strategies, managing winter feeding and calving areas, and the proper location of concentrated livestock holding facilities are important factors in maintaining the health and productivity of riparian areas along the Yellowstone River.

    - **Livestock Grazing Strategies:** Livestock grazing strategies should be developed for the riparian corridor that promote the age and structural diversity of native plant communities that are necessary for the long-term sustainability of riparian forest and riverine wetlands. Grazing strategies will be site-specific depending upon landowner objectives, type(s) of livestock, river reach characteristics, and the native plant community being managed. The supplemental document *Yellowstone River Recommendations – Practical Applications with a Cumulative Effects Perspective – 2015* provides guidelines on season of use, grazing intensity and duration, distribution of livestock, rotation grazing, and vegetation cover monitoring.

- **Feeding and Calving Pastures:** Riparian pastures where livestock are held for prolonged periods, such as winter feeding or calving areas, are often a challenge for managing riparian forest and riverine wetlands (Figure 8-5). Winter feeding concentrates cattle numbers in a relatively small area that can cause long-term damage to both soil and vegetation.
  - Winter feeding or calving areas should be located outside the 50-year floodplain. This may require additional water development, fencing and fabricated wind protection.
  - Livestock concentrated in the riparian/wetland area during the winter should be rotated between multiple wintering sites to minimize impacts. Livestock should not remain at any given winter feeding location for longer than 3 months. Each site should then not be used for more than 2–5 consecutive years.

Figure 8-5 Cattle grazing in the riparian corridor along the Yellowstone River

- **Livestock Holding Facilities:** New holding facilities (e.g., corrals and feedlots) should be built outside the river corridor (100-year floodplain). Old facilities located in the river corridor should eventually be replaced and relocated outside the river corridor. For livestock facilities that are currently being used in the river corridor, manure should be regularly collected and transported off-site to minimize surface and ground water pollution.

- **Small Tracts:** Many exurban tracts include small pastures that hold horses, llamas, cows, sheep, etc. These pastures are often heavily used resulting in soil trampling and compaction, overgrazing, weed infestations, and manure accumulation. It is difficult to properly manage riparian/wetlands vegetation in small exurban pastures, but proper stocking rates, supplemental feed, and rotation grazing can minimize the damage.

Small pasture grazing guidelines:

- Sub-irrigated/irrigated pasture: 3-4 acres/horse stocking rate (6-7 months)
- Dryland pasture: 12-15 acres/horse stocking rate
- Rotation grazing can reduce the acres/horse by as much as 50 percent. Portable power fencing will suffice in most situations.
- For small pastures holding several animals, excluding animals from the river bank with fencing may be necessary.

8.1.6 Invasive Woody Plant Control

Invasive woody plants are a major threat to the Yellowstone River riparian and wetland plant communities. Despite landowner and county weed district attempts to keep them in check, they continue to rapidly expand along the Yellowstone River and tributaries. Russian olive alone occupies about 3,000 acres (Section 4.7.10.2) of the 100-year floodplain and generally increases in a downstream direction.

Russian olive (

Figure 8-6) and saltcedar are the two major woody invasive species that pose serious threats to the integrity and function of riparian and floodplain areas along the Yellowstone River. Common buckthorn is a new invasive species that has recently been discovered on the lower Yellowstone River.

Figure 8-6 Russian olive is aggressively spreading along the Yellowstone River

The following are methods of control based upon infestation levels:

- **Uninfested Sites - Prevention:** There are tracts along the Yellowstone River where neither Russian olive nor saltcedar are present. The cheapest and most effective means to combat invasive woody plants is through proper land management that promotes excellent perennial native grass/shrub/tree cover and minimizes ground disturbance. Additionally, the adoption of an aggressive, early detection and rapid response approach – “search and destroy” – of new woody invasive plant infestations is critical.

- **Light Infestations:** On tracts where invasive woody plants are scattered, total removal of all invasive plants is a realistic goal. New invasive plants like common buckthorn should be especially targeted. Once a tract is clear of all invasive plants, enter into a prevention mode to keep the site uninfested. This will require a frequent walk-through to detect new sprouts from previously treated areas or young plants generated from seed.

- **Moderate Infestations:** Moderate infestations include small patches of invasive plants and/or multiple individual plants growing throughout the tract. These areas usually require a short-term approach of containing the infestation, targeting older trees that set seed, and a long-term process to eventually eradicate all invasive plants. Annual detection and control will be necessary for many years after removal to eliminate new plants being generated from the seed bank.

- **Dense Infestations:** Dense stands of invasive plants can be large and totally exclusive of all native plants. The short-term goal is containment to keep the infestation from spreading. For the long-term, targeting older seed-bearing trees and working the fringes of large patches will slowly shrink the infestation.

Woody Invasive Plant Control Alternatives (For chemical applications, contact the local weed district for recommendations on the appropriate herbicide(s) and rates).

- **Cut Stump Herbicide Application:** Older, larger diameter plants can be treated using a low volume application of herbicide to a freshly-cut stump just above ground level. For best results, the stump should be sprayed within 10 minutes of being cut. Retreatment of sprouts the following year will be necessary.

- **Foliar Herbicide Application:** Apply to stems and leaves of invasive plants less than 6 feet high. This method may affect non-targeted native plants and is generally not recommended except for sprouts from previously treated plants or new seedlings. Aerial herbicide applications in the riparian areas are never recommended.

- **Basal Herbicide Application:** Apply basal herbicide to small plants (stems less than 2-3 inches diameter, less than 8 feet high) using a backpack or ATV mounted sprayer from spring to fall.

- **Manual Removal:** Young plants (up to one year old and less than 2 feet high) can be hand pulled or grubbed out if the infestations are light.

- **Mechanical Treatment:** Mechanical removal by heavy equipment is not recommended in riparian areas. The level of disturbance can open an area for infestations of other noxious weeds and may severely affect native plants. This type of treatment may be applicable in pastures and along irrigation canals. Treatment requires follow-up to treat root sprouts and new seedlings.

8.1.7 Noxious Weed Control

Noxious weeds are found throughout the Yellowstone River corridor and have one of the largest economic and ecological impacts on the riparian and wetland plant communities. They continue to expand their range, not just along the Yellowstone River, but on nearly every tributary. Several landowners and county weed districts have carried out aggressive noxious weed control programs over the last couple decades with limited success.

Noxious Weeds: The major noxious weed infestations along the Yellowstone River include leafy spurge, spotted knapweed, Russian knapweed, houndstongue, and Canada thistle.

The following outline suggests methods for combating noxious weeds. Each landowner should develop a detailed weed management plan that is unique to their property. The local weed district staff can assist with developing this plan.

- **Early Detection and Plant Identification:** Learn to identify noxious weeds common to the area and the growth characteristics of each plant (roots, flower color, seed type, leaf shape, etc.). Throughout the growing season, repeatedly inspect your land for the presence of noxious weeds. When new infestations are discovered, mark the spot on the ground and/or map. Document the site with GPS coordinates.

- **Chemical Control:** Use herbicides that can be safely used in riparian areas or near surface water. Spot spraying noxious weeds using a backpack or ATV mounted sprayer will minimize damage to native riparian plants. Aerial applications of herbicide on a riparian area should never be used. Consult with the local weed district on recommended chemical herbicides and application rates.

- **Mechanical Control:** Hand pulling or clipping may be applicable if the density of weeds is low, the plants are relatively young, and they reproduce by seed rather than roots. For example, light infestations of houndstongue and spotted knapweed may be controlled through mechanical means since they are short-lived and have a tap root. However, perennial noxious weeds such as Russian knapweed or leafy spurge with their extensive root systems require a different approach.

- **Biological Control:** This method of control primarily uses insects to kill or stress specific noxious weeds. Biological control is effective, but rarely successful as a standalone treatment. Contact your local weed district to see if biological control agents are available for noxious weeds growing in your area.

- **Integrated Pest Management (IPM):** Noxious weeds are most effectively controlled using an IPM approach. This is a coordinated approach using a combination of treatments (i.e. chemical, biological, and/or mechanical) that are most appropriate and cost-effective in meeting landowner objectives.

Figure 8-7 Leafy spurge has a deep and extensive root system that makes the plant difficult to control

8.1.8 Water Quality - Nutrient Reduction: Agricultural Land Use

Agricultural land uses occupy the vast majority of the Yellowstone River Basin. It is estimated that farm fertilizer contributes up to 40 percent of the nitrogen and 10 percent of the phosphorus load in the basin. Livestock holding facilities, feedlots, and calving areas (manure pack) contribute only 3 percent of the nitrogen, but are responsible for 22 percent of the phosphorus pollution in the basin (Section 4.6.3.4).

Soil Health Management: Soil health management is an integrated system of cropland management practices that focuses on soil health as a way of optimizing nutrient, pesticide, and irrigation water applications, minimizing their loss through surface runoff and deep percolation. Production costs are typically less and crop yields and quality increase over time. The following guidelines should be considered when designing a soil health management system.

- **Undisturbed Root Systems - Reduced Tillage:** Minimize soil disturbance. Tillage will often result in bare or compacted soil that is contrary to good soil health. Undisturbed root systems are key contributors to increased soil water holding capacity, organic matter content and soil structure.

- **Ground Cover:** Keep the soil covered at all times with growing plants or crop residue. Ground cover conserves moisture, reduces soil erosion, suppresses weed growth, and provides habitat for important soil organisms. To maintain adequate amounts of crop residue, the soil should be disturbed as little as possible.

- **Crop Rotation:** A planned sequence of crops provides plant diversity that will help break insect, disease and weed cycles. A guiding principle is that diversity above ground (plants) equals diversity below ground (soil organisms) which is essential for improving soil health. Depending upon landowner objectives, the rotation may involve rotating high residue crops such as corn or wheat with low residue crops such as sugar beets. Using short-term perennial forage plants can be very effective in crop rotations.

- **Cover Crops:** Following the harvest of annual crops, plant a cover crop “cocktail” mix to provide additional ground cover, organic matter, soil nutrients, and livestock forage through the remainder of the growing season.

- **Irrigation Water Management:** For irrigated fields, an efficient sprinkler system is an important component of a soil health management system. Managing water and nutrients with a flood irrigation system is more challenging. Converting a flood irrigation system to a sprinkler system should be considered when setting up the soil health management system.

- **Feeding and Calving Pastures:** Riparian pastures where livestock are held for prolonged periods can be a significant source of nutrients to the river from surface run-off and shallow groundwater returns.

    - Winter feeding or calving areas should be located outside the 50-year floodplain whenever possible. This may require additional water development, permanent or portable fencing and fabricated wind protection.

    - Livestock concentrated in the riparian/wetland area during the winter should be rotated between multiple wintering sites to minimize manure buildup, soil compaction, and damage to riparian vegetation. Livestock should not remain at any given winter feeding location for longer than 3 months. Each site should not be used for more than 2 to 5 consecutive years.

Livestock Holding Facilities: New holding facilities (i.e., corrals and feedlots) should be built outside the river corridor (100-yr floodplain). Existing livestock facilities located in the river corridor should eventually be replaced and relocated outside the river corridor. Until the facilities are relocated, manure should be collected on a regular basis and transported off-site to minimize surface and ground water pollution.

8.1.9 Water Quality - Nutrient Reduction: Residential Development

The upper Yellowstone River (Gardiner to Huntley) has an increasing number of small tracts (less than 1 acre to 20 acres) being developed within the river corridor. These tracts are often associated with river bank features (rock riprap, jetties, retaining walls, dikes, etc.), storm water run-off, septic systems, riparian clearing, and noxious weed infestations. Since they are relatively small, individual tracts usually have a negligible impact on surface and groundwater quality, but cumulatively they pose a growing threat to the long-term water quality of the Yellowstone River and tributaries.

Septic System Management: Poorly designed or neglected septic disposal systems can be sources of excess nutrients to the Yellowstone River and tributaries. These guidelines should be followed to prevent new septic systems from failing and to correct existing systems that are malfunctioning. A number of factors can cause on-site disposal systems to fail, including unsuitable soil conditions, improper design and installation, and poor maintenance practices.

- **New Septic System Installation:**
    - Permits: All new septic systems require an approved county permit before construction can begin. The design and installation must follow the standards outlined in Montana Department of Environmental Quality Circular 4. Septic tank size and drain field configuration are determined by the number of residents in the household, soil type, ground water table, and

the estimated daily volume of wastewater entering the system. If designed and installed correctly, most septic systems will have a lifetime of 20 to 30 years under the best of conditions.

- New Structures: All new structures that require a septic disposal system should be located outside the 100-year floodplain. In the event that a new septic system is approved within the 100-year floodplain, special design considerations need to assure that flood waters never inundate the drain field. It must also be a suitable distance above the ground water table and be located at least 100 feet from any domestic wells. Nearby domestic wells that draw from a shallow ground water aquifer should be tested for bacteria at least once per year, usually in the spring.

- **Existing Septic System Maintenance:**
  - Septic Tank Pumping: Tanks need to be evaluated every two to five years, and pumped if necessary. A record should be kept of septic tank pumping.
  - Drain Field: The area over the drain filed should be a mowed grass cover that is not fertilized. Grass clippings should be removed. Deep-rooted shrubs or trees will clog drain lines and should not be planted on or near a drain field. Do not over-water the area and be sure there is adequate surface drainage.
  - Wastewater: What goes down the drain has the most influence on a septic system's ability to function efficiently and how long it will last before needing expensive repairs or replacement. Avoid the use of a kitchen garbage disposal, do not pour grease or cooking oil down the drain, eliminate caustic drain cleaner for clogged drains, dispose of excess pharmaceuticals in the garbage and not the drain, and generally reduce the volume of household water that enters the septic system.
  - Additives: It is not necessary to use additives to enhance the performance of a properly operating septic system. If microbial activity is low, it is usually because household disinfectants or bleach-based cleaners flushed into the septic system are killing the bacteria. Chemical additives are especially harmful to the septic systems.

8.1.10 Solid Waste Removal

There are several old private and public solid waste dumps along the Yellowstone River. The burial of solid waste along the river by both private landowners and communities was a common practice up until 40 years ago. Most dumps are no longer being used; but as the river moves, some are becoming exposed. Car bodies, sheet metal, lumber, household and agricultural waste, fencing, concrete chunks, and other waste materials are sloughing off eroding banks directly into the active river channel. This material is affecting water quality, degrading important aquatic habitat, and creating a serious safety hazard for river recreationists.

Figure 8-8 Solid waste exposed on river bank

The following guidelines should be considered when removing solid waste from old private and public dump sites located within the Yellowstone River Corridor (100-year floodplain).

- **Dump Site Assessments:** Where on-site assessments have not been completed, they should be initiated on all private and public solid waste sites located within the Yellowstone River Corridor. The first priorities are the solid waste sites located within the CMZ; second priorities are the dump sites located in the 100-year floodplain. Site assessments include a description of solid waste volume and content, nearest disposal locations, post-removal remediation, and estimated costs for removal, disposal, and remediation.
- **Solid Waste Disposal:**
    - **Metal:** For most dumps, the majority of solid waste material includes steel, cast iron, car bodies, tin, and old machinery that can be recycled through a local metal recycler. The money received for the salvaged metal may off-set part of the removal costs.
    - **Used Lumber, Tree Slash, Concrete, and other Garbage:** These items should be disposed of outside the river corridor in an approved landfill, composted, or recycled. There may be a landfill disposal cost if a large volume of non-recyclable material needs to be disposed.
    - **Pesticide Containers:** Pesticide containers, whether plastic or metal, can be accepted into the Montana Department of Agriculture's disposal program. It is a non-regulatory service program that accepts pesticide containers at four or five collections sites throughout Montana, usually in September. The service is free unless there are a large number of containers or they contain

dioxin or heavy metals. Contact Montana Extension Service or the Montana Department of Agriculture for specific locations and dates. Licensed pesticide applicators will receive a monetary credit when they participate in the disposal program.

  - **Hazardous Waste:** Most old dumps will not have hazardous waste in them. However, during the site assessment or while the material is being removed, if hazardous materials are discovered, the county solid waste management department should be contacted to find out how best to handle and dispose of the material.

  - **Contaminated Soil:** In the event that contaminated soils are discovered during the site assessment or during excavation, the soil should be collected, and depending upon the type of contaminant, either transported to an approved disposal site or thinly spread on a field outside the river corridor.

- **Site Reclamation:** Following the removal of the solid waste, all disturbed areas should be reclaimed. The site should be graded to the natural floodplain elevation and planted with native grasses, shrubs and trees. Aggressively control weeds for three years on disturbed areas. If material is removed off the river bank, bank stabilization may be necessary. Refer to Section 8.1.4 and the *Yellowstone River Recommendations – Practical Applications with a Cumulative Effects Perspective – 2015* for design guidelines and recommendations.

Osprey Nests: A solid waste material that is directly affecting ospreys is plastic baling twine. Ospreys line their nests with soft materials such as moss and grass, but they also pick up baling twine left in fields and fence posts. It is estimated that 10-15 percent of osprey chicks are killed annually by becoming tangled in baling twine brought to their nests. Livestock producers should properly dispose of plastic baling twine immediately after it is removed from the bale.

8.1.11 Irrigation Water Management

Inefficient irrigation systems may cause soil degradation, water quality problems, water shortages, and often require substantial inputs of labor, energy, and capital to operate them. On the other hand, a well-managed irrigation system has infrastructure that is well designed and makes efficient use of the water taken from the river. Irrigation systems can be multi-user with a common headgate and conveyance system that delivers water to thousands of acres, or they can be relatively small, single user systems, and service just a few fields. Regardless of size, an effective irrigation system is designed to be fully compatible with the crops being grown, the amount of water withdrawn, and the proximity of the irrigation system to the river.

This YRRP outlines guidelines and planning considerations for making decisions about irrigation water management systems for large multi-user systems as well as small single-user systems. The three major components of an irrigation water management system include the headworks, conveyance, and on-farm distribution.

<u>**Irrigation Headworks**</u> include all structures located in or near the river channel that make it possible to withdraw water from the river and divert it into an irrigation canal or pipeline.

- **Pumps:** Ideally, pump sites are located on a stable reach of the river where water depths are sufficient for pumping and a power source is readily available. There are two types of pumps used on the Yellowstone River:

  - <u>Permanent Pumps</u>: Permanent pumping stations are often used on the Yellowstone River by multi-user groups that require a high volume of water. For most systems, a permanent pumping station is used only if the irrigation system cannot be served adequately by a portable pump. When constructing new or relocating permanent irrigation pump stations, site location is critical. If possible, a pumping station should not be located where the channel is continually shifting or where there is evidence of channel scour or gravel/silt deposition. Active river bends should be avoided due to high channel migration rates and the never-ending expense of protecting the structure.

  - Portable Pumps: Portable pumps are the most common headworks for landowners who irrigate along the Yellowstone River. Portable pumps can be quickly pulled back from the river during high water events and periods of non-use. Maintenance is low and seldom do they need expensive bank armoring to protect them. They are easily relocated to accommodate river channel changes, although moving a pump may require authorization from the Montana DNRC for a "point of diversion" change.

  - Fish and Debris Screens: Pump screens reduce plugging of pump inlets from floating debris and algae that block water flow and may damage the pump. An effective screen will limit the capture of juvenile fish into the irrigation system. Manual cleaning of pump screens requires constant attention, especially in late summer. It is often worth the investment to purchase a self-cleaning screen that will save time, fuel, and maintenance costs. Fish screens vary greatly in cost based upon the size of pump inlet, mechanical verses self-cleaning, and other site conditions.

- **Diversions/Check Structures:** There are nearly two dozen irrigation headworks on the Yellowstone River including headgates, in-channel diversions, and/or check structures that divert water into the irrigation system. They range from multi-million dollar cross-channel structures to simple rock weirs that extend a short distance out from the headgate.
  .
  - Cross-Channel Structures: There are six high-head, cross-channel check structures on the Yellowstone River that withdraw large volumes of water during the irrigation season. Most of these structures limit or prevent upstream fish passage and pose a safety hazard to recreationists. Designs to rebuild or retrofit these structures should accommodate fish passage, prevent fish from being entrained into the irrigation system, be able to withstand high flows and winter ice, divert a reliable volume of water into the system, incorporate measuring devices, and provide watercraft passage. This requires a complex design and substantial financial resources that will not be possible unless a strong partnership is forged between the water users and other vested interests (nonprofit organizations, state and federal agencies).

  - Low-Head Permanent Structures: Less than twenty low-head irrigation diversions/check structures exist on the Yellowstone River. They are usually constructed using large rocks that extend part way into the channel. These rock structures are subject to high energy flows, floating debris, and winter ice. A detailed design addressing rock gradation, rock placement/alignment, sediment transport, and debris passage is crucial to structure effectiveness and longevity. Water measurement devices should also be incorporated into the headworks.

  - Seasonal Low-Head Structures: There are opportunities on the Yellowstone River to use seasonal irrigation diversions/check structures. There are several types, but portable concrete blocks (6.' to 8 feet long) are commonly used across Montana. These structures are placed in the river for a few months during late summer, low flow months. They are removed after the irrigation season, leaving the channel unobstructed for the remainder of the year. Seasonal structures may be especially applicable on secondary channels. They are low maintenance; however, it is critical that they be removed from the river channel at the end of each irrigation season.

Irrigation Conveyance is the method used to deliver water from the irrigation headworks to the on-farm distribution system(s). This is usually accomplished through an open canal or buried pipeline.

Conveyance efficiency is determined by how much water is lost between the headworks and the irrigated fields. This loss is usually due to canal seepage and evaporation. Long canals in porous soils can lose 40 percent or more of their water from seepage. Seepage can have both beneficial and adverse impacts to the adjacent land and river. It is considered to be an important source of aquifer recharge and late summer return flows to the Yellowstone River. Excessive canal seepage can also waterlog and salinize adjacent lands making them unsuitable for crop production. It often affects water quality by contributing elevated concentrations of salt and nutrients to the river.

- **Canal/Ditch Lining:** If a canal or ditch is unable to deliver sufficient water to meet irrigation needs; or if adjacent lands are being waterlogged or salinized, canal lining may be an option.
  - Locate Major Canal Seepage Sections: Before initiating any canal lining, locate the section(s) of canal with the most seepage. This allows the water users to identify the most severe canal seepage problems for treatment. Priority seepage sections can sometimes be identified by simply noting downslope wet areas, although these observations do not always identify the worst seeps. Periodic flow measurements along the canal, over the course of an irrigation season, will quantify the loss and pinpoint the canal sections to treat.
  - Canal Lining: There are several types of canal lining material that include the traditional reinforced concrete and compacted earth liners. New canal liner products that have recently come on the market include various types of synthetic liners. Selection of a liner material is not a simple task. Climate conditions, soil texture, livestock/wildlife access, size of canal, expected longevity, ease of installation, and available budget must all be carefully considered before a selection is made. Once a liner is selected, it is essential that the canal liner be installed by an experienced contractor. The improper installation of canal liners is the most common reason for liner failure.
- **Irrigation Pipelines:** Another option for preventing seepage, evaporation, non-crop vegetative water consumption, and canal breaches is to replace small open canals with a buried pipeline. It is a common practice in the Yellowstone River Valley to use plastic pipelines as an alternative to small canals or ditches. Large diameter reinforced concrete, PVC, or steel pipe is sometimes used to replace sections of large canals; however, high costs usually limit the scope of these projects to short sections.
  - Design Considerations: A detailed field survey and engineering design is necessary to determine the most suitable pipeline material and size. The design will address pressure, volume of water to be conveyed, soil type and depth, pipeline length, and cost. The installation of the pipeline is critical. The pipe, fittings, joints, and couplers should be carefully inspected prior to installation to be sure there are no cracks, holes, discoloration, or other defects. Proper trench dimensions and careful bedding/compaction of the pipe are essential to the effectiveness and longevity of the pipeline. All buried pipelines should be set back from the river's edge to minimize the potential of failure from channel migration.
- **Fish Entrainment:** Fish entrainment is the incidental capture and trapping of fish in an irrigation canal. The location, inlet design, timing, and water volume will often determine an irrigation system's

potential to entrain fish. Depending upon fish species and river location, some factors may be more important than others. Only a few canal systems on the Yellowstone River have been evaluated for fish entrainment, but it is likely that some are a significant source of mortality for Yellowstone River fish.

- **Canal Assessment:** Before a fish entrainment prevention project is initiated, the irrigation management system should be assessed to determine fish species and abundance in the conveyance canal. The assessment would include estimated mortality rates and whether fish, once entrained, have the opportunity to find their way back to the river via irrigation waste ditches or control structures. This assessment would be completed by Montana Fish, Wildlife & Parks or other qualified fish biologists.
- **Fish Screens:** A physical inventory of pumps, irrigation canals and diversion structures on the Yellowstone River and seven major tributaries indicate that 16 percent of the irrigation withdrawal structures are screened. A common approach to prevent fish entrainment is to install a screen on the headgate, the pump intake, or at the upper end of the irrigation canal. Most fish screens are designed to block fish from entering an irrigation canal and/or to divert them back to the river through a bypass structure. To maximize fish screen effectiveness, the design needs to consider approach velocities, swimming abilities of the targeted fish, volume of floating debris, installation costs, and long-term maintenance requirements.
- **Canal Drawdown:** At the end of the irrigation season, irrigation headworks are often abruptly closed causing a sudden change in the water level, reducing the canal to a series of disconnected pools where fish and aquatic animals become stranded. For irrigation headworks not screened, a slow incremental draw-down of the canal at the end of the irrigation season may cue some fish to move out of the system and back to the river on their own.

Irrigation on-Farm Distribution Systems: There are two broad categories of on-farm irrigation water distribution systems being used along the Yellowstone River: flood and sprinklers. The types of crops grown in the Yellowstone River Valley do not lend themselves to drip/micro-irrigation although this technique is used for shelterbelts and residential landscaping. Flood irrigation efficiencies range from 15 to 60 percent while sprinkler irrigation efficiencies are much higher (60 to 85 percent).

- **Sprinkler Irrigation:** Along the Yellowstone River, nearly 15 percent of the irrigated cropland is served by sprinkler systems. Over the last 20 years, center pivot sprinklers have become increasingly popular following recent improvements in sprinkler system technology. Sprinkler systems using older technology (laterally-moving wheel lines and hand-moved pipe) have steadily declined during that same period. An on-farm sprinkler system will typically use less than half the water required for flood irrigation. Sprinkler irrigation requires less labor and can increase crop yields by as much as 40 percent. The tradeoffs are the initial equipment/installation investment, on-going energy costs, more consumptive use of water, and less return flows to augment late summer flows.

- **Pivot Sprinkler Design:** A properly designed pivot system will be economical, highly reliable, efficient, and have low operation and maintenance (O&M) requirements. The pivot should be equipped with drop tubes to limit evaporative losses and wind drift. Pivots should be located outside the channel migration zone (CMZ) to preempt the need to eventually relocate the system or to install expensive bank armor to protect it.

Figure 8-9 Over the last 20 years, an increasing number of flood irrigation systems have been converted to sprinkler irrigation

- **Soil Health Management:** Sprinkler irrigation is more amendable to reduced tillage, optimization of fertilizer and pesticide use, and the inclusion of cover crops in crop rotations. Sprinkler irrigation is an important component of the soil health management approach that is becoming increasingly popular in the Yellowstone River Valley. Through the efficient application of irrigation water by sprinklers, there is typically little or no runoff, resulting in very little sediment, nutrients, and pesticides being discharged into the river. Deep percolation is also curtailed, significantly reducing nutrient and pesticide leaching to the shallow ground water. Converting from an on-farm flood irrigation system to sprinklers should be seriously considered when adopting a soil health management program.

- **Flood Irrigation:** Even with the recent trend to convert flood irrigation to sprinkler irrigation, over 85 percent of the irrigated fields in the Yellowstone River Valley are still under flood irrigation. Land features – such as contour ditches, border dikes, and furrows – have traditionally been used to help control water movement and distribution.

  Flood irrigation is seldom as efficient as sprinkler irrigation; however there are ways to improve water use efficiency.

  - <u>On-Farm Conveyance Pipelines:</u> Replacement of irrigation delivery ditches with buried pipe can reduce seepage, ditch erosion, and maintenance costs. Ditches with flow capacities of 5 cfs or less are candidates for buried pipeline. Most on-farm pipelines are 24 inch diameter or less, with 8 inch to 15-inch pipelines being most common. A detailed field survey and engineering design is necessary to determine the most suitable pipeline material and size.
  - <u>Field Leveling and Shaping:</u> Periodically, flood irrigated fields should be releveled or reshaped to eliminate variations in field gradient and side slopes to allow more control of water advance and improve the uniformity of soil saturation. Laser level technology provides opportunities for setting precise field grades and improving water application.

- Gated Pipe: Since the late 1980s, gated pipe has made a big difference on flood irrigated lands in the Yellowstone River Basin. It is versatile enough to be used on steep upper-basin haylands as well as flat lower-basin sugar beets. Gated pipe eliminates the need for contour or field ditches thereby reducing water evaporation, seepage, and ditch erosion. Water management is more efficient and labor requirements are much less than traditional flood irrigation. For some irrigated lands, primarily furrow crops, modifications to the gated pipe system such as surge flows (timed releases) and cablegation (moveable plug) further improve water use efficiency.
- Tailwater Recovery: Irrigation tailwater recovery and reuse systems are applicable to any flood irrigated system in which a significant quantity of irrigation water runs off the end of the irrigated field. It is not unusual for runoff to be 15 percent or more of the amount of water applied to the field. Most tailwater systems reuse 0.5 to 1.5 acre-feet per acre of irrigated land per year. The tailwater system consists of a ditch at the bottom of the field to capture excess water and deliver it to a small storage reservoir. The system would include a pump and pipeline to convey waste water back to the irrigated field for reuse. The capture and reuse of irrigation tailwater significantly reduces the sediment and nutrients that would otherwise be discharged into the river.

8.1.12 Oil/Gas/Brine Water Pipeline Crossings

Following the 2011 rupture and resulting oil spill from the ExxonMobil Silvertip Pipeline near Laurel, the YRCDC commissioned a hazardous material pipeline risk assessment that was completed in 2012. A second pipeline oil spill on the Yellowstone River near Glendive (January 2015) again heightened public awareness of the vulnerability of these pipelines and the environmental damage that can result from these spills. The pipeline risk assessment shows the presence of 39 pipelines intersecting the Yellowstone River Channel Migration Zone (CMZ) at 21 crossings. Thirty of the pipelines cross the channel while nine pipelines are located within the CMZ (Section 4.6.7.2).

Factors that affect pipeline failure risk are either internal or external. Internal factors are those factors intrinsic to the pipeline itself, such as corrosion, weld failure or age. External factors are those that are a function of the environment through which the pipeline must pass. These external factors include lateral channel migration and channel bed scour that may expose shallowly buried pipelines. Depth of cover, bank armoring, and “pinch points” such as bridges can exacerbate the potential for pipeline exposure by concentrating erosive forces.

The following are YRRP guidelines for new and existing pipeline crossings on the Yellowstone River and tributaries.

- **Horizontal Directional Drilling:** All new pipeline crossings will use Horizontal Directional Drilling (HDD) technology that places the pipeline at a minimum of 30 feet beneath the river channel bottom. Crossings will be located on a stable straight channel reach where possible. River bends and braided sections should be avoided. The HDD entry and exit points will lie outside the 100-year CMZ boundary. All drilling pads, staging areas and disturbed areas will be reclaimed following the HDD pipeline installation.
    - **Existing Pipelines:** All existing at-risk pipelines that were installed using open-trench technology will be replaced using HDD technology following with the same general criteria as for new pipelines. Pipelines that do not cross the river, but are buried within the CMZ, should be inspected regularly and eventually be relocated outside the CMZ.

  - **Abandoned Pipelines:** All abandoned pipelines should be removed within the CMZ. Old bank armor and physical features associated with the abandoned pipeline should be evaluated to determine if they should be removed as well.
  - **Oversight:** State and federal oversight agencies will be encouraged to insist that HDD technology be used on all new pipeline crossings on the Yellowstone River and the perennial/intermittent tributaries that feed into the Yellowstone River.

- **Spill Detection:** Spill detection and remote shutoff valve technology will be incorporated into all pipelines to minimize the volume of spilled material and expedite response time.

- **Pipeline Inspections:** Initiate regular annual inspections of pipeline crossings with special attention given after major flood and ice jam events.

8.1.13 Altered Flows

The two primary reasons for Yellowstone River hydrology alterations are due to irrigation withdrawals throughout the Yellowstone River Basin and large storage reservoirs located in the Bighorn River Basin.

- **Irrigation Withdrawals:** There has been a reduction in historic peak flows and summer low flows from Gardiner to the Big Horn River confluence due to irrigation withdrawals. Below the Bighorn River confluence, both irrigation withdrawals and Bighorn Basin storage reservoirs combine to significantly affect the river's hydrology. Refer to Section 8.1.11 Irrigation Water Management for irrigation water management efficiency guidelines.

- **Bighorn River Basin:** Traditional peak flows on the lower Yellowstone River have decreased about 23 percent for the 2-year flood (13,700 cfs) and 16 percent (19,100 cfs) for the 100-year flood due to Bighorn River storage reservoir releases (Section 4.3.2.1). The influence from these reservoirs also lowers late summer low flows on the Yellowstone River. Fall and winter flows are slightly higher. These flow alterations have a significant effect on channel-forming processes, aquatic habitat, riparian forest recruitment, and water quality.

  - **Bighorn River System Issues Group:** The YRCDC will actively participate in the Bighorn River System Issues Group that currently meets twice during the year. The Bighorn River Systems Issues Group was formed to identify, explore, and recommend alternative courses of action to local, state, and federal entities responsible for managing the Bighorn Lake and River system. The Bureau of Reclamation organizes and facilitates all Bighorn River System Issues Group meetings. The YRCDC will represent lower Yellowstone River interests and, when possible, encourage adjustments of Bighorn River hydrologic operations to mitigate its effects on the lower Yellowstone River.

- **Water Marketing:** The YRCDC will collaborate with Montana DNRC to determine opportunities, challenges, and water right implications of using water marketing and banking as tools for maintaining or improving flows in the Yellowstone River and tributaries.

8.1.14 Channel Migration Zone

The Yellowstone River is a relatively unique river. It is not controlled and locked in place like many rivers in the West. Over most of its length, the river still has the ability to move laterally across its floodplain and create avulsions (new channels such as meander cut-offs). The Channel Migration Zone (CMZ) maps define areas along the Yellowstone River that are prone to channel erosion over the next 100 years. CMZ map boundaries are based on local geologic mapping and measured rates of lateral channel change derived from fifty years of historic aerial photography.

Landowners and resource managers are often called upon to make land use decisions along the Yellowstone River in the absence of substantive information regarding channel migration. The CMZ maps are intended to:

- Improve Yellowstone Valley residents' understanding of the dynamic nature of this large river system.
- Identify potential channel migration threats to existing and proposed infrastructure within the river corridor that would encourage the location (or relocation) of infrastructure outside the CMZ.
- Identify potential land loss from channel migration to help landowners determine the economic cost/benefits of installing bank armoring.
- Identify restoration opportunities where bank armor and floodplain dikes have restricted the natural CMZ erosion processes.
- Support local and regional land use planning by identifying areas within the Yellowstone River corridor that are at high risk due to channel migration. CMZ maps can be incorporated into discussions between regulatory, planning, and development interests on proposed projects within the river corridor.

8.1.15 Fish Passage and Entrainment

Fish passage and entrainment are two resource issues intertwined with irrigation along the Yellowstone River. Where irrigation water is diverted by structures spanning the entire river channel, the movements or migrations of various fish species can be greatly affected. Where water is withdrawn from the river either via gravity diversions or pumps, there is a risk of entraining fish. Studies have shown that the distributions and movements of many Yellowstone River fish species, one of which is the federally endangered pallid sturgeon, are affected by low-head diversion dams. In addition, studies of unscreened irrigation systems indicate that substantial numbers of fish are often entrained in the system. Across the United States and in Montana, fish passage and entrainment protection measures have been used to restore habitat connectivity and sustain healthy fish populations without negatively affecting agricultural practices.

- **Fish Passage - Cross Channel Structures:** There are six cross-channel check structures on the Yellowstone River that withdraw large volumes of water during the irrigation season. Several of these structures limit or prevent upstream fish passage. Designs to rebuild or retrofit these structures must accommodate fish passage, prevent fish from being entrained into the irrigation system, be able to withstand high flows and winter ice, and still divert a reliable volume of water into the system. This requires a complex design and substantial financial resources that is often not possible unless a strong partnership is forged between the water users and other vested interest groups (nonprofit organizations, state and federal agencies).
- **Fish Passage - Tributaries:** Yellowstone River tributaries are important to both cold-water and warm-water species by providing spawning and larval rearing habitat. Several tributaries have fish passage barriers such as road/railroad crossings, irrigation structures, and in-channel ponds. Montana Fish, Wildlife and Parks (MFWP) have identified many of these tributary barriers, but more evaluations are needed.
- **Fish Entrainment – Irrigation Conveyance Systems:** An outreach strategy is needed to identify irrigation districts/companies along the Yellowstone River and tributaries that are willing to have their canals evaluated for fish entrainment. For canals found to have a significant fish entrainment issue, voluntary, practical solutions between MFWP and the water users need to be developed that will

reduce the number of fish captured in the canal while not affecting the volume of irrigation water transported through the canal or significantly increasing the operation and maintenance requirements of the system.

Figure 8-10 Channel catfish, found on the Yellowstone River, is especially susceptible to fish passage barriers

9.0 PUBLIC PARTICIPATION AND TRIBAL COORDINATION

A wide variety of stakeholders have been involved through this study, as described in Section 1.2. There has been a remarkable amount of committed participation for the duration of this study. Table 9-1 includes a listing of stakeholders involved in the study.

Table 9-1
Primary stakeholders involved in the cumulative effects assessment

Conservation Districts	**Federal Agencies**
Custer County Conservation District	U.S. Bureau of Reclamation
Dawson County Conservation District	U.S.D.A. Natural Resources Conservation Service
Park County Conservation District	U.S. Army Corps of Engineers
Prairie County Conservation District	U.S. Fish and Wildlife Service
Richland County Conservation District	U.S. Geological Survey
Rosebud County Conservation District	
Stillwater County Conservation District	**Universities**
Sweet Grass County Conservation District	Montana State University - Billings
Treasure County Conservation District	Montana State University - Bozeman
Yellowstone County Conservation District	Rocky Mountain College
McKenzie County Conservation District (ND)	
	Other Organizations
State Agencies	The Nature Conservancy
Montana Department of Natural Resources and Conservation	Yellowstone Valley Audubon
Montana Fish Wildlife and Parks	Northern Great Plains Joint Venture
Montana State Library	Yellowstone River Forum
	Our Montana
	Montana Audubon
	Natural Resource Consulting Firms

9.1 Public Meetings

The draft Yellowstone River Cumulative Effects Analysis report was circulated for public, agency, and tribal review from October 5 through November 5, 2015. During the public review period, three workshops were held at the following locations. All meetings began at 7:00 p.m. and included presentations and opportunity for public comment and questions. Presentations and meeting sign in sheets are included in Appendix 12.

Tuesday October 13, 2015
Big Timber, Montana
Sweet Grass County High School - Cafeteria
501 West Fourth Avenue
Big Timber, MT

Wednesday October 14, 2015
Huntley, Montana
Yellowstone Valley Electric Cooperative - Community Room
150 Cooperative Way
Junction of I-94 and Huntley exit (south side of Interstate) Huntley, MT

Thursday October 15, 2015
Glendive, Montana
Glendive Alliance Church - Community Room
105 Highland Park Road
Junction of I-94 and Hwy 16 (quarter mile north of Interstate) Glendive, MT

Approximately 80 people attended the three workshops and asked a variety of questions and provided verbal comments. The questions and comments discussed during the meetings are categorized into the following themes.

- Background and history of the study
- Sources of data for the study and interest in where documents will be available
- Flooding concerns along the river, including ice jams.
- Funding opportunities
- Permit requirements to implement recommended actions
- Will state and federal agencies support recommended actions?

No written comments were provided either at the workshops or to the comment address provided in the notice of availability for the document.

9.2 Tribal Coordination

Coordination letters were distributed to the following tribes seeking comment. Copies of the letters are included in Appendix 12, as of December 1, 2015 no comments have been received.

Table 9-2
Tribal Coordination

Assiniboine and Sioux Tribes of Fort Peck
Cheyenne River Sioux Tribe
Crow Nation
Eastern Shoshone Tribe
Fort Belknap Indian Community
Mandan, Hidatsa & Arikara Nation
Northern Arapaho Tribe
Northern Cheyenne Tribe
Standing Rock Sioux Tribe
Chippewa Cree Tribe of the Rocky Boys' Reservation

9.3 Document Availability

This document and associated data and study products will be available in hard copy and online for future use. The report is available at the website: http://yellowstonerivercouncil.org/resources.php

In addition a number of the products that came out of this study will be available at the Conservation Districts, such as the Channel Migration Zone (CMZ) maps and floodplain maps. Additionally, the Montana State Library hosts a data clearinghouse for the data and reports generated for the Yellowstone River Corridor located at the following website: http://geoinfo.msl.mt.gov/Home/data/yellowstone_river_corridor_resource_clearinghouse. All project data and final reports will be housed at this site.

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