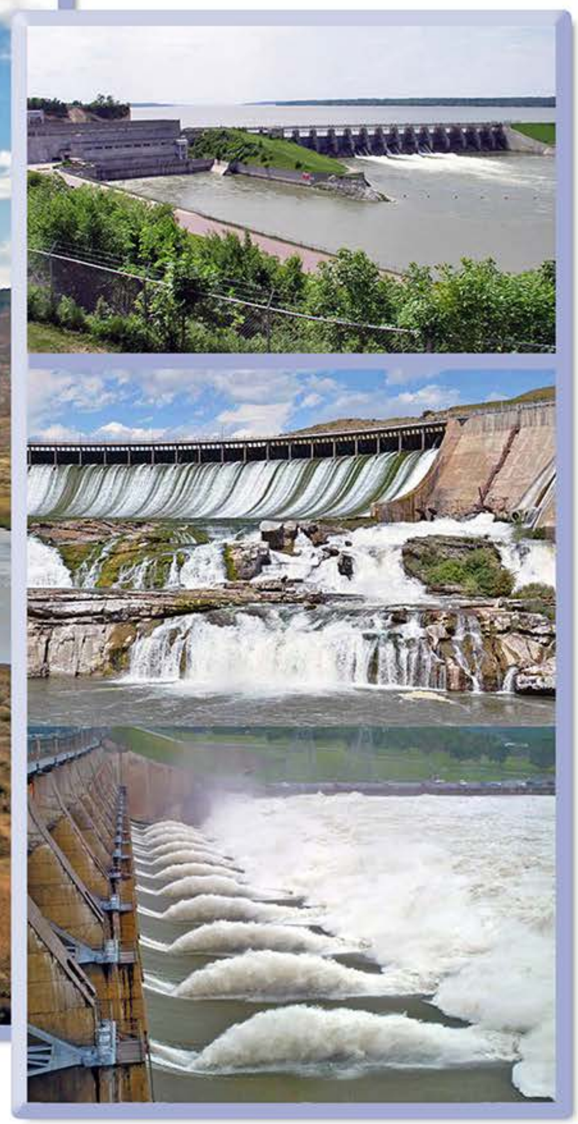
RECLAMATION
Managing Water in the West

SECURE Water Act Section 9503(c)—Reclamation Climate Change and Water 2016

Chapter 6: Missouri River Basin



U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

U.S. Department of the Interior
Bureau of Reclamation

March 2016

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

SECURE Water Act Section 9503(c) Report to Congress

Chapter 6: Missouri River Basin

Prepared for

United States Congress

Prepared by

U.S. Department of the Interior
Bureau of Reclamation

U.S. Department of the Interior
Bureau of Reclamation
Policy and Administration
Denver, Colorado

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Acronyms and Abbreviations

AF	acre-feet
AFY	acre-feet per year
cfs	cubic feet per second
DNRC	Montana Department of Natural Resources and Conservation
ESA	Endangered Species Act
IJC	International Joint Commission
MRRIC	Missouri River Recovery Implementation Committee
Pick-Sloan Program	Pick-Sloan Missouri Basin Program
Reclamation	U.S. Bureau of Reclamation
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WaterSMART	Sustain and Manage America's Resources for Tomorrow

About this Chapter

This summary chapter is part of the 2016 SECURE Water Act Report to Congress prepared by the Bureau of Reclamation (Reclamation) in accordance with Section 9503 of the SECURE Water Act. The 2016 SECURE Water Act Report follows and builds on the first SECURE Water Act Report, submitted to Congress in 2011,[1] which characterized the impacts of warmer temperatures, changes to precipitation and snowpack, and changes to the timing and quantity of streamflow runoff across the West.

This chapter provides a basin-specific summary for the Missouri River Basin. This chapter is organized as follows:

- **Section 1**: Description of the river basin setting,
- **Section 2**: Overview of the implications for various water and environmental resources,
- **Section 3**: Potential adaptation strategies considered to address basin water supply and demand imbalances, and
- **Section 4**: Coordination activities within the basin to build climate resilience.

Missouri River Basin Setting

States: Colorado, Iowa, Kansas, Minnesota, Missouri, Montana, Nebraska, North Dakota, South Dakota, and Wyoming

Major U.S. Cities: Great Falls, Billings, Casper, Cheyenne, Denver, Rapid City, Lincoln, Omaha, Bismarck, Pierre, Sioux City, Kansas City, St. Louis, and Topeka

International: Canada

River Length: 2,500 miles

River Basin Area: 500,000 square miles

Major River Uses: Municipal, Agricultural, Hydropower, Recreation, Flood Control, Navigation, and Fish and Wildlife

Notable Reclamation Facilities: Reclamation has constructed more than 40 dams on Missouri River tributaries that have helped with agriculture development in the basin

This chapter provides updated information from Reclamation studies completed or initiated in the basin over the past five years. The key studies referenced in this chapter include the Upper Missouri River Basin Impact Assessment, Missouri River Basin Headwaters Basin Study, St. Mary and Milk River Basins Study, Republican River Basin Study, and Niobrara River Basin Study. Additional information relevant to the Missouri River Basin, including the latest climate and hydrology projections for the basin, is included in Chapter 2: Hydrology and Climate Assessment.

[1] The first SECURE Water Act Report, submitted to Congress in 2011 is available on the Reclamation website: www.usbr.gov/climate/secure/docs/2011secure/2011SECUREreport.pdf.

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1 Basin Setting

At 2,565 miles in length, the Missouri River is the longest river in the United States and the third longest river in the world. Its watershed spans more than 500,000 square miles through portions of seven states and one Canadian province, making it the largest watershed within the United States (U.S.). The headwater tributaries of the Missouri River form along the Continental Divide in southwestern Montana. These tributaries convey snowmelt runoff to the Gallatin, Madison, and Jefferson Rivers, which converge near Three Forks, Montana, to create the Missouri River. From the headwaters in Three Forks, the Missouri River flows through Montana, North Dakota, South Dakota, Nebraska, Iowa, Kansas, and Missouri to its confluence with the Mississippi River near St. Louis, Missouri. Basin topography varies from glaciated mountain ranges to flat and rolling grasslands to wide floodplain valleys. Climate and vegetation are similarly varied, ranging from alpine tundra environments to subhumid grasslands and temperate forests. The majority of the basin consists of rolling plains, with agriculture the predominant use of the land.

Despite the river's length and the watershed's size, the Missouri River produces annual yields (40 million acre-feet [MAF]) that are significantly less than either the Columbia (199 MAF) or Ohio (181 MAF) Rivers, both of which are more than 1,000 miles shorter than the Missouri River. This low annual flow, in combination with a large watershed and socioeconomic factors, contributes to conflict in management and use of the river throughout the Missouri River Basin.

The Missouri River crosses the 98th meridian in northeastern South Dakota. This meridian roughly divides the U.S. between relatively arid and humid (i.e., 20 inches or more of annual precipitation) climates. The Missouri River Basin exhibits strong temperature and precipitation gradients consistent with larger continental gradients in North America. Mean annual temperatures decrease northward, and average annual precipitation increases from west to east. In the portions of the basin west of the 98th meridian, most precipitation falls as snow. Most of the precipitation in the eastern basin falls as rain.

1.1 Missouri River Basin Studies Overview

The Missouri River Basin presents unique management challenges due to the size and complexity of the basin. Particularly, Reclamation recognizes the difficulty in serving both international obligations and differing interstate needs across a large geographic area, all with relatively low yields.

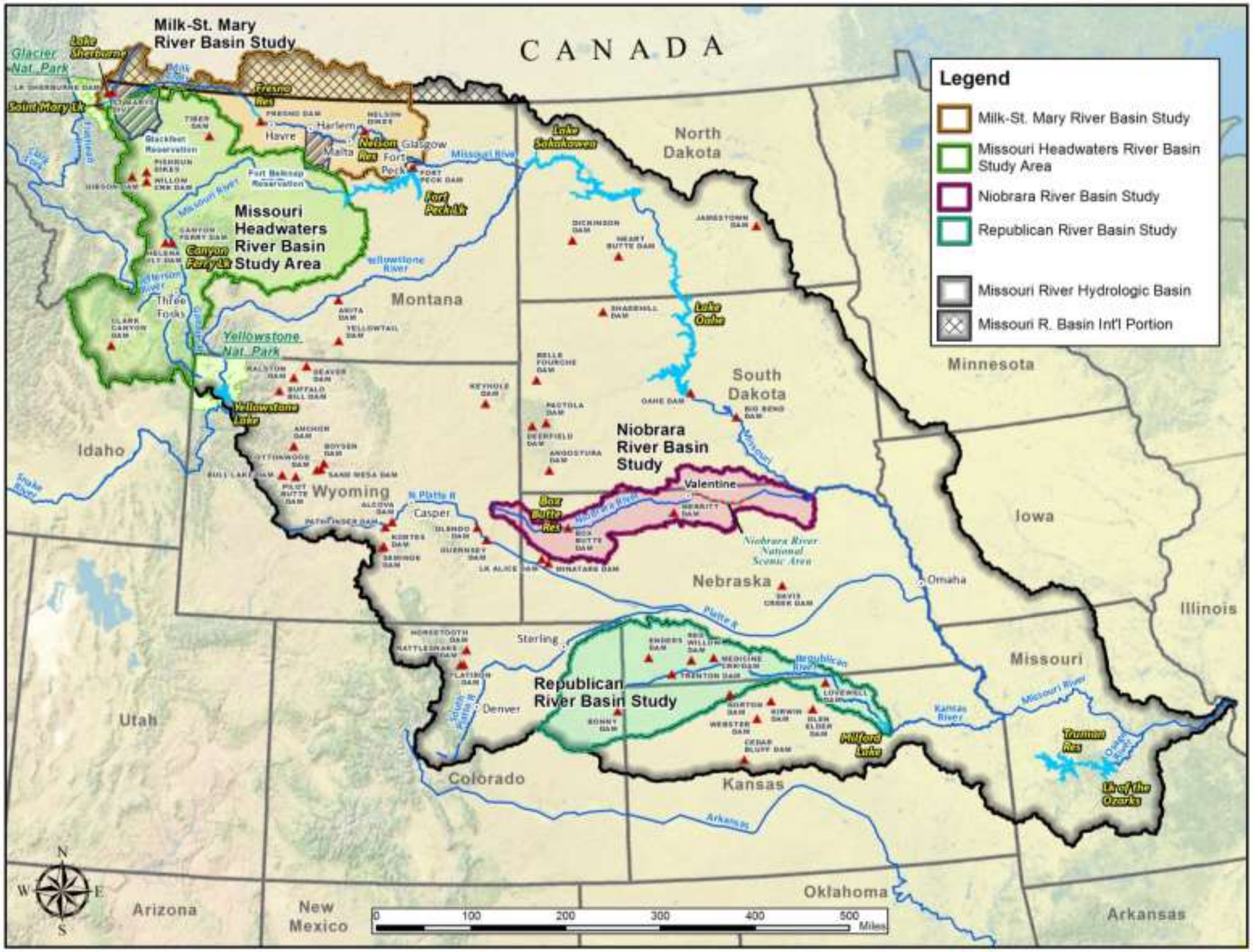

Figure 6–1. Missouri River Basin overview map.

Reclamation has undertaken several Climate Impacts Assessments and Basin Studies in order to evaluate the reliability of the Reclamation's irrigation and water systems to meet the current and future needs in the basin, with an emphasis on the impacts of future climate variability. Impacts Assessments and Basin Studies are funded and conducted by Reclamation through the Basin Study Program under the Department of the Interior's WaterSMART (Sustain and Manage America's Resources for Tomorrow) Program. The Basin Studies are conducted in coordination with stakeholders in the Missouri River Basin. The purpose of the Basin Studies is to define current and future imbalances in water supply and demand in the basin and subbasins over a long-term planning horizon, and to develop and analyze adaptation and mitigation strategies to address those imbalances. Since 2009, the following five climate impacts assessments and basin studies have been undertaken in the Missouri River Basin:

- **Upper Missouri River Basin Climate Impacts Assessment**: Reclamation is conducting the Upper Missouri River Basin Climate Impacts Assessment to determine baseline risks to water supplies and demands in order to establish a foundation for more in-depth analyses and the development of adaptation strategies in the Missouri River Headwaters Basin Study. This study is expected to be complete in 2016.
- **Missouri River Headwaters Basin Study**: Reclamation is collaborating with the Montana Department of Natural Resources and Conservation to fund the basin study. The study area encompasses the Missouri River Basin headwaters in Montana from the Continental Divide to the Landusky and Mosby gauges, both upstream of Fort Peck Reservoir.
- **St. Mary and Milk River Basins Study:** Reclamation collaborated with the Montana Department of Natural Resources and Conservation to fund the study, which was completed in 2010. The study area encompasses north-central Montana, southern Alberta, and Saskatchewan in Canada, and includes the Blackfeet and Fort Belknap Indian Reservations.
- **Republican River Basin Study**: Reclamation collaborated with the state governments of Colorado, Nebraska, and Kansas to fund the study. The Republican River Basin Study area covers the entire Republican River Basin in eastern Colorado, southern Nebraska, and northern Kansas, down to the Clay Center gauging station in Kansas. This study was released in March 2016.
- **Niobrara River Basin Study**: Reclamation collaborated with the Nebraska Department of Natural Resources to fund the study. The study area is located along the Niobrara River in northern Nebraska. This study is expected to be complete in 2016.

To date, the St. Mary River, Milk River, Republican River, and Niobrara River Basin Studies have been completed. The following sections focus on water management, water resources impacts, and adaptation strategies within these three subbasins of the Missouri River.

1.2 Management

Since the U.S. Army Corps of Engineers (USACE) began debris-snagging and other river maintenance activities in 1838, issues along the Missouri River related to competing uses of water have been commonplace. USACE and Reclamation developed separate water management plans focused on flood control, navigation, and water scarcity and irrigation, respectively. Congress passed the Flood Control Act of 1944 that included both USACE and Reclamation management plans for the river that came to be known as the Pick-Sloan Missouri Basin Program (Pick-Sloan Program). The Flood Control Act of 1944 also included the O'Mahoney-Millikin Amendment, making navigation subordinate to beneficial consumptive uses of water west of the 98th meridian. Section 9 of the Flood Control Act of 1944, as amended, authorized the Pick-Sloan Program for flood control, navigation, irrigation, power, water supply, recreation, fish and wildlife, and water quality purposes. In response to the Pick-Sloan Program, USACE constructed six mainstem dams on the Missouri River (Figure 6–2), and Reclamation constructed more than 40 dams on basin tributaries (Figure 6–1). Reclamation's development in the basin focused on agricultural irrigation in the upper basin states west of the 98th meridian.

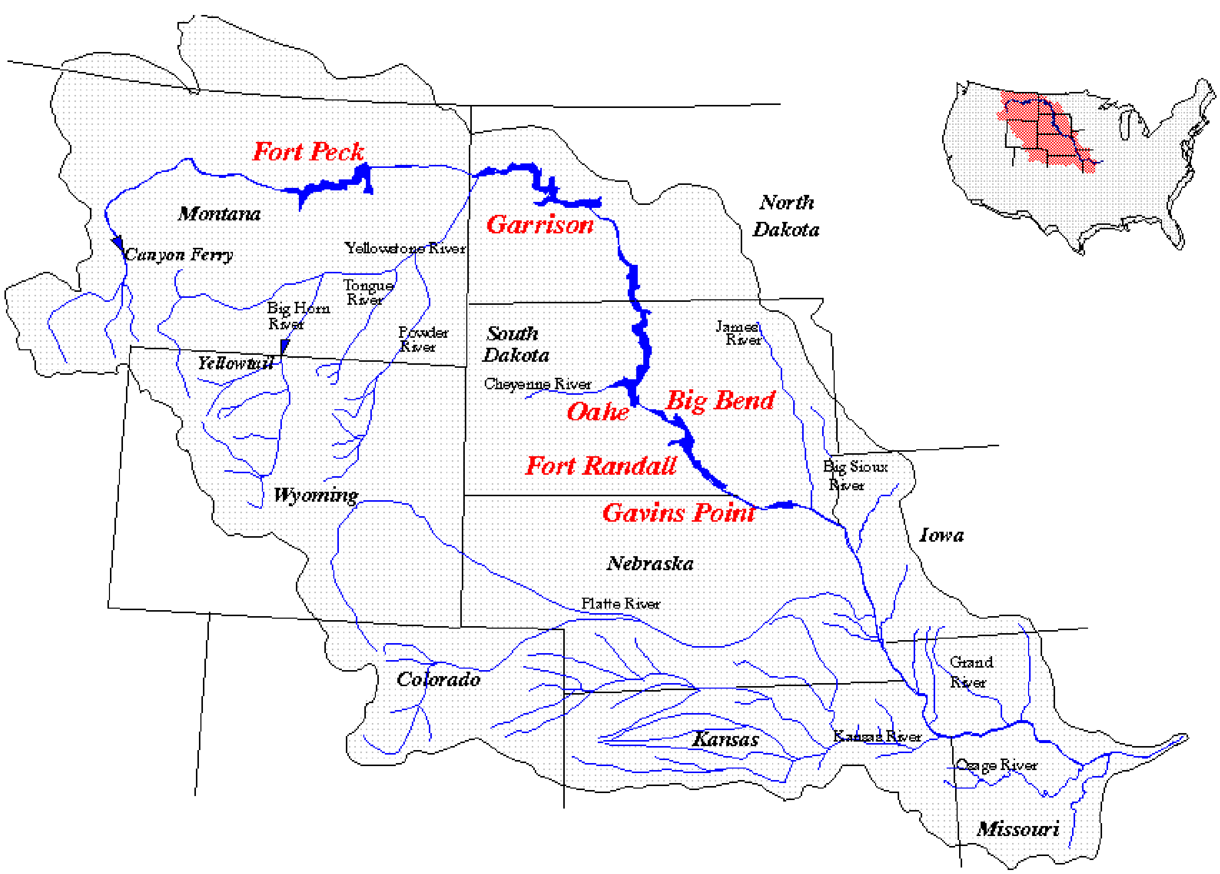

Figure 6–2. Major U.S. Army Corps of Engineers dams on the Missouri River.

St. Mary River and Milk River Setting and Management

The St. Mary River and Milk River subbasins run from the Rocky Mountains in the west to the Milk River confluence with the Missouri River below Fort Peck Dam in the east. The St. Mary River rises in Glacier National Park, in northern Montana, flowing northeast through the Blackfeet Reservation into Canada, to its confluence with Oldman River near Lethbridge, Alberta, below Fort Peck Reservoir. The Milk River originates in the foothills of the Rocky Mountains on the Blackfeet Reservation, flowing northeasterly into Alberta for about 200 river miles before crossing the border again into Hill County, Montana. Thereafter, the river flows in an easterly direction for 490 river miles until joining the Missouri River near Nashua, Montana. The Milk River system is augmented by a trans-basin diversion from the St. Mary River Basin.

Reclamation's Milk River Project includes the facilities in both the St. Mary River and Milk River Basins, and these facilities are operated as a synchronized system. The Milk River Project irrigates about 121,000 acres in the Milk River Basin. Principal crops are alfalfa, grass hay, oats, wheat, and barley. Approximately 50,000 people depend on the Milk River Project for municipal, rural, and industrial water supplies, including the communities of Havre, Chinook, and Harlem, and the Fort Belknap and Blackfeet Indian Reservations.

In the northernmost portion of the basin, the United States and Canada share the waters of the St. Mary and Milk Rivers in accordance with the Boundary Waters Treaty of 1909, the International Joint Commission (IJC) 1921 Order, and subsequent Letter of Intent. Current administration of the Treaty, combined with infrastructure limitations, has resulted in the United States receiving less than its share of St. Mary River flow and Canada receiving less than its share of Milk River flow.

A Water Rights Compact between the State of Montana and the Gros Ventre and Assiniboine Tribes of the Fort Belknap Indian Reservation was ratified by the Montana State Legislature and signed by the Governor in 2001. The compact entitles the Tribes to divert up to 645 cfs from the U.S. share of the natural flow of the Milk River. The compact negotiated between the Blackfeet Tribe and the State of Montana was approved by the Montana Legislature and recommended for further action by the Blackfeet Tribal Business Council in 2009. The Compacts are not yet in effect since they have not been approved by Congress; if approved by Congress, the Compact would give the Tribe the right to 50,000 acre-feet per year (AFY) from the St. Mary drainage, other than from Lee Creek and Willow Creek. For Lee Creek and Willow Creek, the Tribe has a right to all natural flow available to the United States under the Boundary Waters Treaty, and all groundwater in the St. Mary River drainage not subject to the Boundary Waters Treaty. After satisfaction of all water rights arising under state law and full development, the Tribe would have a right to the remaining portion of the United States' share of the St. Mary River under the Boundary Waters Treaty.

In 1973, the State of Montana began a state-wide adjudication of all water right claims that existed prior to July 1, 1973. This included reserved water rights associated with Indian and other federal reservations. Claims on the St. Mary and Milk Rivers are being examined by the Montana Department of Natural Resources and Conservation (DNRC) and are being adjudicated by the Montana Water Court. The Montana Water Court has issued temporary or preliminary decrees in the St. Mary River Basin and the Milk River Basin. The DNRC has completed all initial examinations in the St. Mary River Basin and the Milk River Basin by the June 30, 2015, deadline for final re-examinations. The parties involved in the adjudication proceedings are working toward resolution in 2023, along with a deadline in 2028 for completion of the claims prior to final decrees being issued by the Montana Water Court.

Republican River Setting and Management

The Republican River Basin, located in the southern portion of the Missouri River Basin, is an important region for the states of Nebraska, Colorado, and Kansas that includes highly productive agricultural lands, large reservoirs with recreational and wildlife habitat features, and established communities that rely on the agriculturally driven economy and the water supplies that sustain it. The Republican River originates in the high plains of northeastern Colorado, western Kansas, and southern Nebraska. Tributaries originating in northeastern Colorado and western Nebraska flow to the southeast to join the northern side of the mainstem. Tributaries originating primarily in northwestern Kansas flow in a northeastern direction to join the south side of the mainstem. In total, the Republican River flows east for 453 miles until it joins with the Smoky Hill River at Junction City, Kanas, to form the Kansas River.

The Republican River Basin covers approximately 16 million acres and partially overlies the Ogallala Aquifer, which is a component of the High Plains Aquifer[2], the largest groundwater system in North America that spans eight western states (Figure 6–3). Groundwater is the primary water supply for most of the irrigated agriculture in the basin, and is the sole supply for municipal, industrial, and domestic uses throughout most the basin. There are many demands on the limited water supply within the Republican River Basin, including irrigation, recreation, fish and wildlife, and municipalities. By far, the largest demands come from groundwater wells that pump water from the Ogallala Aquifer for agricultural irrigation in order to support cultivation of various crops (winter wheat, grain sorghum, soybeans, corn, and sugar beets).

[2] The High Plains aquifer underlies an area of about 174,000 square miles that extends through parts of eight states. The aquifer is the principal source of water in one of the major agricultural areas of the U.S.

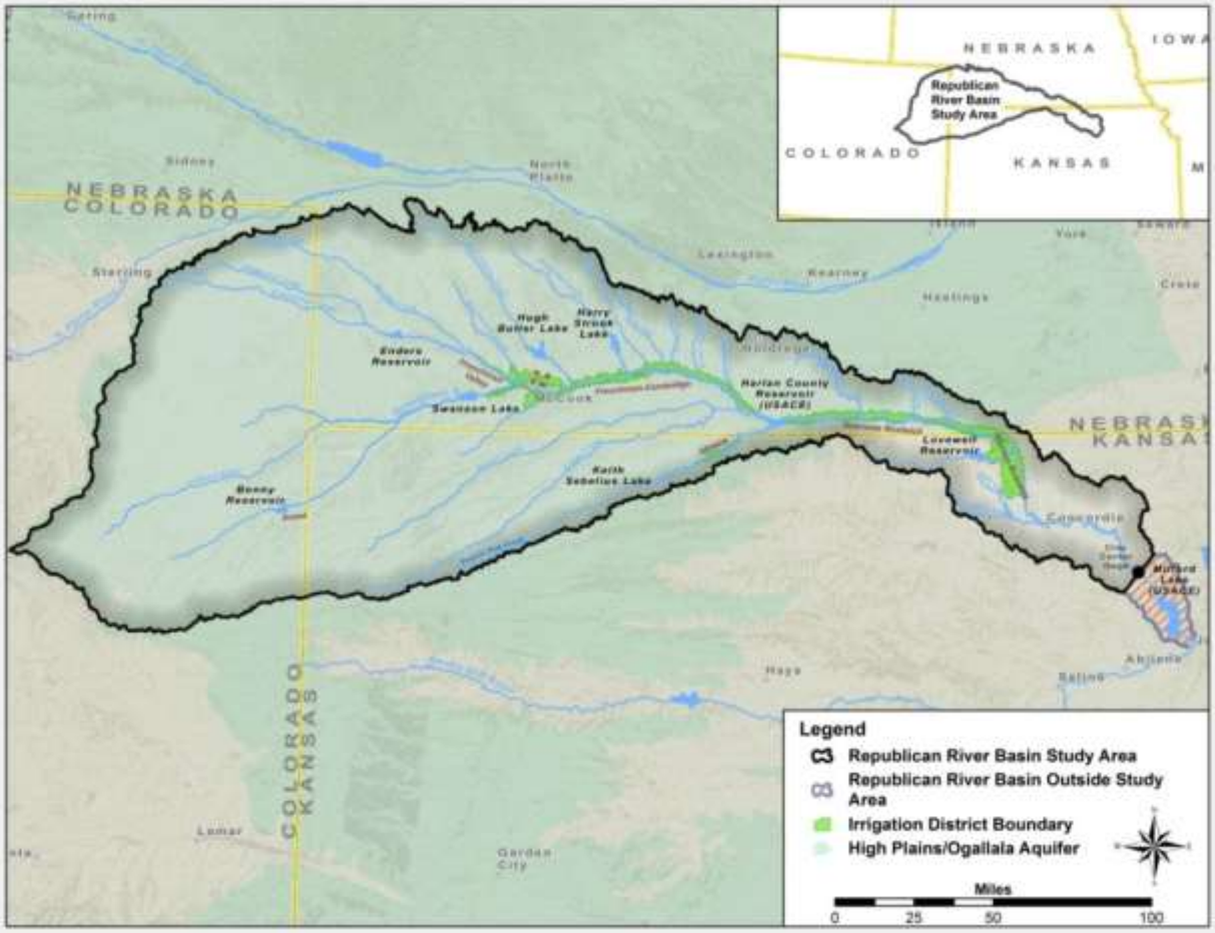

Figure 6–3. Republican River Basin study area. Source: Reclamation, 2016 (Republican).

Reclamation facilities within the Republican River Basin were constructed in the 1940s as part of Reclamation’s Pick-Sloan Missouri River Program. The features in the study area include a system of seven Bureau of Reclamation reservoirs, one USACE reservoir, and six irrigation districts. The Reclamation reservoirs include Bonny Reservoir, Swanson Lake, Enders Reservoir, Hugh Butler Lake, Harry Strunk Lake, Keith Sebelius Lake, and Lovewell Reservoir; the USACE reservoir is Harlan County Lake.

The water management issues in the Republican River Basin are complex and involve a long history of stakeholder involvement and activities by Colorado, Nebraska, and Kansas. The Republican River is subject to an interstate compact among Colorado, Nebraska, and Kansas. The Republican River Compact, established in 1943, divides the basin’s water supply across eastern Colorado, northwest Kansas, and southwest Nebraska. The high water demands within the basin and declines in adjacent streamflows have created intense competition for limited water supplies, which has ultimately resulted in litigation on compliance with the Republican River Compact. In 1998, the State of Kansas filed a lawsuit against the State of Nebraska, asserting that Nebraska had allowed diversions that exceeded their legal share. Following litigation in the U.S. Supreme Court, the States entered into a Final Settlement Stipulation, approved by the U.S. Supreme Court in 2003. Under the Final Settlement Stipulation, most streamflow depletions caused by surface water and groundwater diversions for beneficial consumptive use are included in the determination and allocation of the virgin water supply of the basin. As a result, interaction between groundwater and surface water is a key component of water management within the basin.

Niobrara River Setting and Management

The Niobrara River Basin originates on the high plains of eastern Wyoming and spans 535 miles east, to the point where the Niobrara River empties into the Missouri River near Niobrara, Nebraska. The Niobrara River Basin drains 12,600 square miles of northern Nebraska and adjacent parts of Wyoming and South Dakota. The basin currently supports about 600,000 irrigated acres and provides municipal water use for approximately 20,000 people, as well as water for hydropower, recreation, and wildlife. In 1991, a 76-mile stretch of the river was designated as the Niobrara National Scenic River, just downstream from the Fort Niobrara National Wildlife Refuge (Figure 6–4). The Niobrara River Basin and the underlying High Plains Aquifer are the primary water resources in the watershed. Temperature and precipitation vary greatly along the Niobrara, both spatially and temporally.

Figure 6–4. Aerial view of the Niobrara River.

Replenished by seepage from various formations, the Niobrara is a predominantly aquifer-supplied river. Szilagyi et al. (2002) found that in the river's upper reaches, 70 to 90 percent of its flow can be attributed to seepage from groundwater. Near its origin in southeastern Wyoming, the river cuts through the water-bearing Arikaree Formation. As it bends through Sioux, Dawes, and Sheridan Counties, Nebraska, it gradually begins to run over the more prolific Ogallala Formation. Water management in the Upper Niobrara River Basin is guided by the Niobrara River Compact between the States of Wyoming and Nebraska.

Within Nebraska, the basin has two Reclamation projects for irrigation: the Mirage Flats Project (11,662 acres) and the Ainsworth Unit (35,000 acres). The basin has one non-Federal hydropower facility, Spencer Hydropower. Reclamation facilities in the Niobrara River Basin include Box Butte Dam and Reservoir (Mirage Flats Project) and Merritt Dam and Reservoir (Sandhills Division, Ainsworth Unit of the Pick-Sloan Missouri Basin Program). Box Butte Dam and Reservoir lie in the arid western Niobrara River Valley, which is dominated by dense cottonwood and willow trees and is surrounded by rolling prairie. The Ainsworth Unit, including Merritt Dam and Reservoir, is located southeast of the Mirage Flats Project, within the northern portion of the Sandhills Region of Nebraska. The Sandhills Region is dominated by rough hills made of fine, wind-blown sands and the occasional broad, shallow valley. In the lower reaches, the valleys often become narrow and deeply entrenched. Merritt Dam and Reservoir are built on the Snake River, where the valley narrows and becomes entrenched.

2 Analysis of Impacts to Water Resources

In the Missouri River Basin the local climate and impacts to water resources varies considerably within the basin. For example, annual average temperatures are generally cooler in the high-elevation upper reaches located in the western portion of the upper basin. Warmer temperatures are observed over lower-lying plains to the east and south. Key findings related to projected changes in temperature, precipitation, snowpack, and runoff are presented below.

- **Temperature** is expected to follow a similar general trend to current basin conditions with the upper reaches of the basin (e.g., Missouri River at Canyon Ferry) projected to see a smaller relative increase in mean annual temperature during the 21st century, than the middle and lower reaches of the basin (e.g., Missouri River at Omaha).
- **Precipitation** projections are geographically complex for the Missouri River Basin. Precipitation is generally greater in the western upper reaches along the mountains and over the southeastern reaches, and lesser in the High Plains region located in between these two areas. Projections indicate that the Great Plains region will continue to experience the kind of inter-annual to inter-decadal variations in precipitation that it has experienced historically (Reclamation, 2016 [Projections]).
- **Drought** and heat waves are expected to increase in frequency due to climatic changes. Climate change may also exacerbate hazards such as tornadoes, droughts, and floods and will increase economic losses in the future (University of Nebraska-Lincoln, 2014).
- **Snowpack** is expected to diminish during the cool season due to increasing temperature (late autumn through early spring) and the availability of snowmelt to sustain runoff during the warm season (late spring through early autumn). Decreases in snowpack are projected to be more substantial over the portions of the basin where baseline cool-season temperatures generally are closer to freezing thresholds and are more sensitive to projected warming. This is particularly the case for the eastern plains.
- **Seasonality and timing of runoff** also are projected to change. Historically, unimpaired streamflow in the basin has a seasonal peak in May and June, corresponding with the seasonality of precipitation. Warming is expected to lead to more rainfall runoff, rather than snowpack accumulation, during the cool season. This is especially true for the higher-elevation watersheds.

Changes in water supply and reservoir operations due to climate change may have cascading effects to water allocations from year to year, which in turn could trigger changes in water use (e.g., crop types, cropping dates, environmental flow targets, transfers among different uses, hydropower production, and recreation). Key findings related to projected changes in demand are summarized below.

- Agricultural irrigation is the predominant water demand on Reclamation reservoir systems within the western reaches of the Missouri River Basin. Given that the atmosphere's moisture-holding capacity increases when air temperature increases, plant water consumption and surface water evaporation associated with agricultural demands should increase in a warming climate.
- Additionally, agricultural water demand could decrease due to crop failures caused by changes in pests and diseases in the future. Seasonal volumes of agricultural water demand could increase if growing seasons become longer, and if farming practices adapt to this opportunity by planting more crop cycles per growing season.
- Climate change could also result in changed demand for in-stream flow or reservoir release to satisfy other system objectives, including ecosystem support, hydropower generation, municipal and industrial water deliveries, river and reservoir navigation, and recreational uses.
- Water demands for endangered species and other fish and wildlife could increase with ecosystem impacts due to warmer air and water temperatures and resulting hydrologic impacts (i.e., runoff timing).
- Diversions and consumptive use by industrial cooling facilities are predicted to increase, since these processes will function less efficiently with warmer air and water temperatures. The timing of these diversions and those for hydropower production also could be a factor in ecosystem demands and navigation and recreational water uses.

The Missouri River Basin is highly complex and Reclamation must manage its facilities within the basin to meet a vast array of objectives and needs, such as making reliable water deliveries, producing hydropower, providing recreational opportunities and flood control, and managing fish and wildlife (including Federally listed species and their habitat). The impacts of climate change on Reclamation's ability to satisfy these key management objectives are described in the following sections.

2.1 Water Delivery

Changes in climate, particularly shifts in the timing of runoff, are expected to affect Reclamation's ability to meet contracted and scheduled water deliveries. Mean annual basin runoff is projected to increase as much as 9.7 percent, but higher variability is also expected in sub-basin runoff. Moisture falling as rain instead of snow at lower elevations may increase the wintertime runoff with decreased runoff during the summer. For example, in the St. Mary River/Milk River area, the irrigation season is projected to begin approximately 7 days earlier, and irrigation shortages are expected to increase. Earlier calls on reservoir releases for irrigation water will lead to a stronger reliance on stored water during the late summer months.

Figure 6–5. St. Mary Diversion Dam, Montana.

Additionally, aging infrastructure is expected to affect water deliveries. The actual conveyance capacity of the St. Mary Canal has been reduced from 850 cfs to about 650 cfs at the St. Mary siphon as a result of seepage, slides, and canal bank slumping. Reclamation and the irrigation districts perform replacement and extraordinary maintenance on St. Mary facilities dependent on funding availability.

2.2 Hydropower

Electricity demand from hydropower generation and other sources generally correlates with temperature (Scott and Huang, 2007). Hydroelectric generation to satisfy demands is sensitive to climatic changes that may affect basin precipitation, river discharge (amount and timing), and reservoir water levels. Hydropower operations also are affected indirectly when climate change affects air temperatures, humidity, or wind patterns (Bull et al., 2007). Climatic changes that result in decreased reservoir inflow or disrupt traditional timing of inflows could adversely affect hydropower generation. Alternatively, increases in average flows would increase hydropower production. Projected increases in water availability under climate change may benefit the production of hydropower in this basin.

Figure 6–6. Canyon Ferry Dam and Powerplant, Missouri River.

2.3 Recreation at Reclamation Facilities

Recreation impacts in the Missouri River are varied across the large expanse of recreation facilities within the basin (Figure 6–7). Under drier climate scenarios, a sizable reduction in water levels may be offset by increased visitation estimates due to increases in air temperatures. In these scenarios, warmer air temperatures could draw more visitors to certain reservoirs even if water levels are lower thereby improving the recreational benefits in the basin. Due to the size of this river basin and large number of recreation locations, the impacts of climate change, particularly warming temperatures, could actually result in a significant benefits for the basin through increased flatwater recreation.

Examples of recreation benefits from completed basin studies are included below. In the St. Mary River/Milk River subbasin, elevations are expected to be an average of 1 to 6 feet lower. With lower water elevations in reservoirs and a projected increase in demand for recreational uses at Fresno, Nelson, Sherburne, and Glacier National Park, the demands for flatwater recreation will be satisfied less frequently.

Meanwhile, impacts in the Republican River are varied, with reservoirs resulting in reduced recreation benefits under the warmer and drier climate scenarios and increases in water levels and temperatures leading to increases in recreation visitation. Overall, in the sub-basin, water levels across the April-to-September high-recreation-use season were estimated to decline while temperatures were estimated to increase. In calculating visitor days, the increases in temperature of 5 to 6 degrees Fahrenheit by 2070 outweighed the losses in water levels, resulting in an increase in visitor days, and thus, recreation benefits.

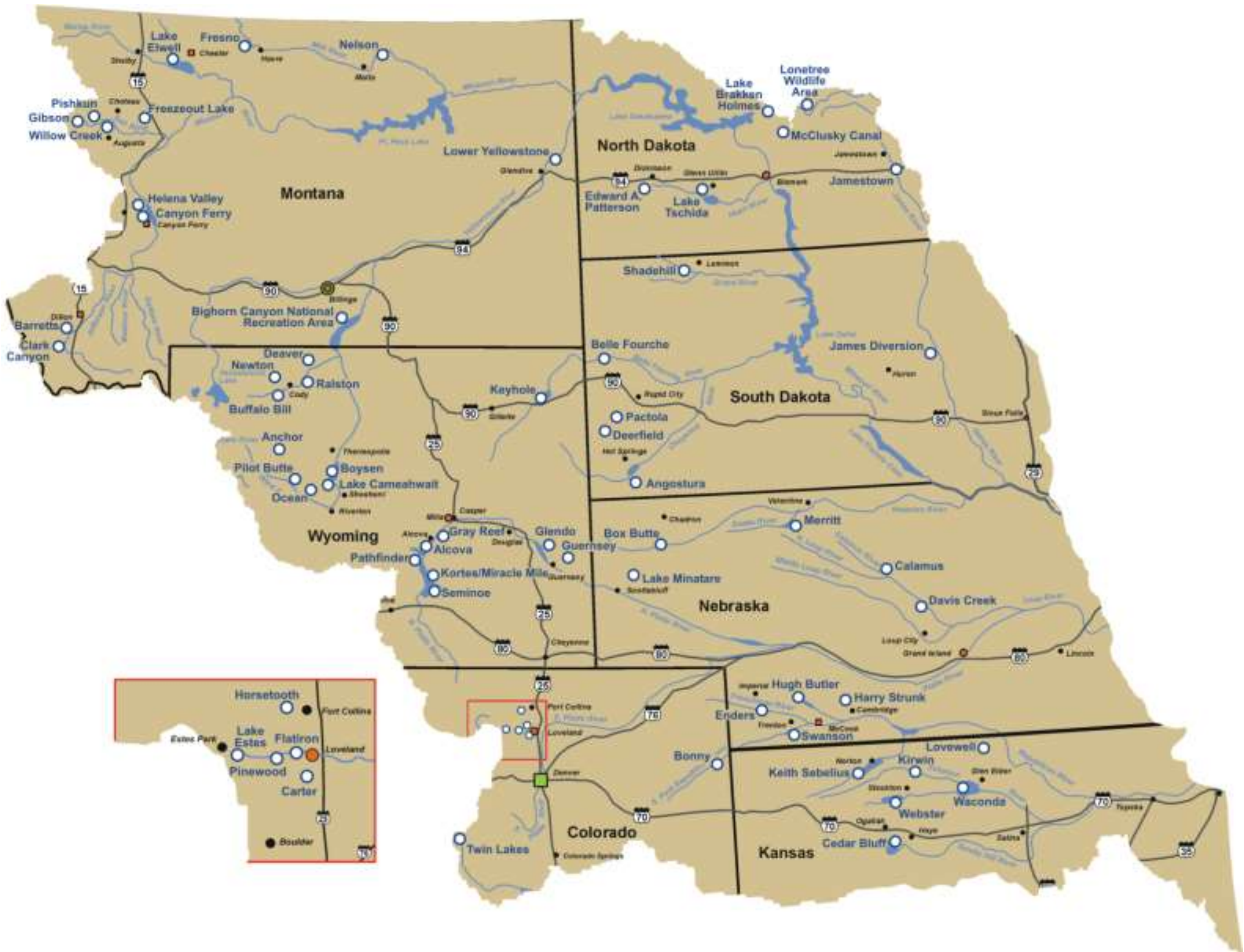

Figure 6– 7. Recreation locations in the Missouri River Basin.

Figure 6–8. Sailboats moored on Canyon Ferry Reservoir, a unit of the Pick-Sloan Missouri Basin Program.

2.4 Flood Management

Historically, unimpaired streamflow in the basin has a seasonal peak in May and June, corresponding with the seasonality of precipitation. Warming is expected to lead to more rainfall runoff, rather than snowpack accumulation, during the cool season. This is especially true for the higher-elevation watersheds.

Presently, Lake Sherburne and Fresno Reservoir provide flood control benefits by storing water during the peak runoff period. Some of these benefits are derived by reducing local damages; for Fresno Reservoir, other benefits are derived by storing water that would have contributed to flooding downstream on the main stem of the Missouri River below Fort Peck Reservoir. Between 1950 and 2010, Lake Sherburne has prevented $7.9 million in flood damages, while Fresno Reservoir has prevented $14.2 million in flood damages, according to USACE estimates. A full list of the annual flood control benefits in the Missouri Basin by project are listed in Table 6–1.

Table 6–1. Annual Flood Control Benefits for the Missouri River Basin

Missouri River Basin Project	Accumulated Actual Benefits from 1950 through 2014 ($)
Pick-Sloan Missouri Basin Program Total	2,811,158,100
Sun River Project Total	3,085,600
Milk River Project Total	25,912,900
Shoshone Project Total	30,502,400
Kendrick Project Total	48,553,800
North Platte Project Total	17,741,700
Missouri River Total	**2,936,954,500**

2.5 Fish and Wildlife Habitat

Projected climate changes are expected to have an array of interrelated and cascading ecosystem impacts (Janetos et al., 2008). At present, most projected impacts are primarily associated with increases in air and water temperatures and decreases in reservoir level and include increased stress on fisheries that are sensitive to a warming aquatic habitat. For example, Fresno Reservoir is expected to frequently fall below the Montana Fish, Wildlife, and Parks' recommended reservoir level of 2,560 feet for fisheries habitat. Other impacts of a decrease in reservoir level include increased water temperature and reduced dissolved oxygen, which are detrimental to native aquatic organisms. Conversely, lower lake levels at the Bowdoin National Wildlife Refuge may increase habitat for shoreline nesting birds.

Warmer air and water temperatures could potentially improve habitat for quagga mussels and other invasive species, which, in turn, may additionally affect maintenance of hydraulic structures and increased risk of watershed vegetation disturbances due to increased fire potential. Other warming-related impacts include pole-ward shifts in the geographic range of various species and impacts on the arrival and departure of migratory species.

Climate changes could decrease the effectiveness of chemical or biological agents used to control invasive species (Hellman et al., 2008). Warmer water temperatures also could spur the growth of algae, declines in water quality (Lettenmaier et al., 2008), and changes in species composition. In addition, landscape fragmentation is increasing in the context of energy development activities, for example, in the northern Great Plains. A highly fragmented landscape will hinder adaptation of species when climate change alters habitat composition and timing of plant development cycles (Shafer et al., 2014). The magnitude of expected changes will exceed those experienced in the last century.

Dunnell and Travers (2011) report that some spring-flowering species have advanced their first flowering time, some fall species have delayed their first flowering, and some species have not changed. Given the importance of flowering timing for reproductive success, the changing climate in the Great Plains is expected to have long-term ecological and evolutionary consequences for native plant species.

A warming climate is projected to result in fewer wetlands in the Missouri River Basin. If temperature and precipitation trends of the 20th century continue, a steeper west-to-east gradient in wetness may further shrink wetland acreage in the most productive portion of the prairie pothole region (Millett et al., 2009). Prairie wetlands were found to be more sensitive to changes in temperature than to changes in precipitation, and increased temperature scenarios resulted in wetland drying and declining numbers of ponds and ducks (Sorenson et al., 1998). Large increases in precipitation are necessary to offset even small temperature increases. Wetland size, depth, and vegetation characteristics were found to be more sensitive to increases in temperature rather than changes in precipitation (Poiani and Johnson, 1991).

Primary productivity in temperate grasslands was found to be more responsive to precipitation than to temperature, and changes in primary productivity responding to changes in moisture continued up the food web (Hunt et al., 1991). Changes to primary productivity may affect migratory birds by upsetting migratory timing and habitat and food availability. Increased intensity of summer storms, especially those with large hail, is expected to increase avian mortality.

Simulations of 50 years of climate change show losses of soil organic carbon across the entire central Great Plains due to increased temperatures that led to increased decomposition rates (Burke et al., 1991). Some areas were expected to lose 3 percent of the total soil carbon pool. Areas with the highest precipitation (and high initial soil organic matter) suffered the largest loss of organic soil carbon.

Rising nighttime minimum temperatures and their potential effect on grassland productivity in northeastern Colorado were considered by Alward et al. (1999). Minimum temperatures increased 0.3° F per year over the previous 23 years. Averages of seasonal minimum temperatures also exhibited significant warming, with similar trends in winter, spring, and summer. Annual precipitation exhibited a significant linear increase from 9 inches to 19 inches during the same timeframe. The study indicates that for each 1.8° F increase in average spring minimum temperature, aboveground net primary productivity of dominant grasses decreases by nearly one-third. Increased growing season duration is expected primarily to benefit cool-season plants that grow most rapidly early and late in the growing season.

Increases in temperature and reduced precipitation have the potential to reactivate significant areas of now-stabilized or mostly stabilized sand dunes and sheets in the Great Plains (Muhs and Maat, 1993). Some of the areas with the greatest potential increase in dune activity are in central Wyoming, eastern Colorado, and western Kansas. At least one plant listed as endangered (blowout penstemon) under the Endangered Species Act is a species found only in sand dune habitats.

Many ecosystems of the Great Plains are not well suited for accommodating fish distributional shifts that will occur because of climate change, owing to the lack of nearby hydrologic connectivity with higher-latitude and -elevation habitats generally associated with climate change-induced range shifts. Despite uncertainty in precisely how Great Plains fish species distributions may be affected by a warming climate, this lack of hydrologic connection may lead to additional climate-related stress on fish communities in the Great Plains compared to other regions of North America (Pracheil et al., 2014).

2.6 Endangered, Threatened, or Candidate Species

A number of species listed under the Endangered Species Act (ESA) can be found in the St. Mary River and Milk River region (Table 6–2). Endangered species include the black-footed ferret, whooping crane, pallid sturgeon, and interior least tern. Threatened species include the grizzly bear, piping plover, bull trout, and Canada lynx.

Table 6–2. Where Endangered Species Can Be Found within the St. Mary River and Milk River Region

Species	Where Species Has Been Found
Bull trout (east of the Continental Divide)	St. Mary River Basin
Grizzly bear	Near Swiftcurrent Creek on the Blackfeet Reservation, as well as using the St. Mary Canal as a travel corridor
Black-footed ferret	On lands near the Milk River, residing in abandoned prairie dog towns
Whooping crane	Migratory birds that have been documented to migrate through the Milk River Basin in the spring and fall each year
Canada lynx	Use the St. Mary River Basin as a main traveling corridor, and this population of lynx is thought to be the strongest lynx population within the United States
Least tern	Nesting along the banks of the Milk River
Piping plover	In the Milk River Basin, nesting on the shore and islands in Nelson Reservoir, and at Bowdoin National Wildlife Refuge

The U.S. Fish and Wildlife Service (USFWS) listed bull trout as threatened under the ESA in 1999. USFWS identified three areas where Reclamation structures and operations may have adverse impacts on bull trout: lack of winter flows in Swiftcurrent Creek below Sherburne Dam, entrainment into the St. Mary Canal, and passage at the St. Mary Diversion Dam. Reclamation is required to comply with the ESA as it relates to bull trout in its operations of these facilities. In March 2011, Reclamation, in cooperation with the Blackfeet Tribe, National Park Service, USFWS, Milk River Joint Board of Control, St. Mary Rehabilitation Working Group, DNRC, and Bureau of Indian Affairs, completed a value planning study on fish passage and entrainment for the St. Mary Diversion Dam. Reclamation is also completing designs, specifications, and associated environmental documents for fish passage and entrainment for the St. Mary Diversion Dam.Whooping cranes, Eskimo curlews, peregrine falcons, interior least terns, piping plovers, and the American burying beetle occur within the Republican River Basin.

2.7 Water Quality

Typically, water quality problems become more pronounced during droughts when dissolved chemical concentrations and water temperatures are highest, although suspended sediments are higher during high-flow events such as spring runoff. Irrigation can contribute to water quality degradation. Problems typically occur when irrigation diversions result in low river flows and when return flows from fields contain higher concentrations of salts, nutrients, suspended solids, and pesticides.

Sedimentation

Fine-grained sediments are transported by the Milk River downstream to Fresno Reservoir, where they settle and reduce the storage capacity of the reservoir. Reclamation estimated that the reservoir has lost 36,200 acre-feet (AF) (as of May 1999) from its original 129,062 AF storage capacity from sedimentation since it was completed in 1939. Similar rates of sedimentation are expected to continue into the future. Sedimentation in reservoirs will cause a reduction in storage availability and increased evaporation due to shallower and warmer reservoir pools.

3 Potential Adaptation Strategies to Address Vulnerabilities

The Basin Studies conducted in the Missouri River Basin identify potential adaptation strategies that could help reduce the supply and demand imbalances that are projected to result from climate change. Adaptation strategies considered in the St. Mary River/Milk River and the Republican River Basin studies:

- **Canal efficiency:** Methods include lining canals and laterals, putting laterals into pipe, reusing spills and return flows, and adding and improving water measurement sites. Ditch efficiencies could be improved by reducing seepage losses and, in some cases, increasing capacities to meet peak demands.
- **Infrastructure Rehabilitation:** Replacement of aging infrastructure to increase capacity and reduce seepage losses would provide additional water storage. For example, at the St. Mary Canal, the original 850 cfs capacity is reduced to 650 cfs capacity.
- **On-farm efficiencies:** Methods include field leveling, more-efficient flood-irrigation water distribution, converting from flood irrigation to sprinklers, and shorter field runs.
- **Increase storage capacity:** Raise spillway crests, expand current reservoirs, and build new dams and reservoirs (in both Canada and the United States).
- **Expansion of Lovewell Reservoir, KS:** This adaptation strategy involves increase storage in Lovewell Reservoir located 8 miles south of Superior, Nebraska on White Rock Creek. This alternative is subdivided into three options of increasing storage by 16,000, 25,000, or 35,000 AF
- **Swanson Reservoir Augmentation via New Frenchman Creek Pipeline, NE:** These adaptation strategies involve augmentation of Swanson Reservoir by taking advantage of existing available storage and diverting water from either Frenchman Creek or the Republican River. In recent years, Swanson Reservoir has consistently had available storage capacity. This alternative would divert water directly from Frenchman Creek into Swanson Reservoir when storage space is available.
- **Swanson Reservoir Augmentation via New Republican River Pipeline, NE:** This is the same as the prior example, with the exception of water being diverted downstream of the confluence of Frenchman Creek and the Republican River, rather than diverted directly from Frenchman Creek.
- **New Thompson Creek Dam, NE:** This adaptation strategy involves construction of a new dam on Thompson Creek, a tributary to the Republican River, and conveying the water to the Franklin Canal for delivery to NBID in exchange for allowing water to be stored in Harlan County Lake.

4 Coordination Activities

Where opportunities exist, Reclamation participates in coordinated adaptation actions in response to climate stresses. These activities include discussing reservoir operating plans, extending water supplies, conserving water, increasing hydropower production, planning for future operations, and supporting rural water development.

Reclamation coordinates with many entities within the Missouri River Basin. Each spring, Reclamation Area Offices in Montana, Wyoming, and Colorado meet with state government representatives, water users, in-stream and flat-water interests, and others to present tentative reservoir operating plans for comment and discussion. Similar meetings are held for facilities in the Plains States (Dakotas, Nebraska, and Kansas). Reclamation takes into consideration all comments, concerns, and suggestions.

The National Drought Resilience Partnership is a partnership of several Federal agencies that conducts pilots to link drought information such as monitoring, forecasts, outlooks, and early warnings with longer-term drought resilience strategies in critical sectors such as agriculture, municipal water systems, energy, recreation, tourism, and manufacturing. A pilot study is currently ongoing in the Upper Missouri River Basin that leverages the Climate Impact Assessment and Basin Study in the Upper Missouri Headwaters and is the foundation of Federal and state partnerships. The pilot initiative is focused on how improved drought preparedness at the local, state, and tribal levels can be achieved through enhanced coordination of Federal agency resources.

The Federal Highway Administration provided funding through Reclamation to work with the Blackfeet Tribe on the Swiftcurrent/Boulder Creek Bank and Bed Stabilization Project. The project addresses tribal concerns about Reclamation facilities and operations affecting tribal resources by diverting water from Swiftcurrent Creek into Lower St. Mary Lake. Reclamation and the Blackfeet Tribe formed a working group in 2009 to investigate and evaluate alternatives to address these concerns.

Additional coordination activities include long-range planning efforts. Reclamation is also a participating agency in the Missouri River Recovery Implementation Committee (MRRIC). MRRIC was established in 2008 to serve as a basin-wide collaborative forum in which to develop a shared vision and comprehensive plan for Missouri River recovery.

Reclamation continues to support projects ranging from endangered species recovery to rural water supply projects. In the Missouri River Basin, three rural water projects are currently being constructed to serve tribal areas within the basin (Table 6–3).

Table 6–3. Rural Water Projects within the Missouri River Basin

Rural Water Project	Purpose
Garrison Diversion Unit (Pick-Sloan Missouri Basin Program) in North Dakota	Will serve the West Fort Totten area of the Spirit Lake Tribal Reservation
Fort Peck Reservation/Dry Prairie Rural Water System (Montana)	Will assist the Assiniboine Sioux Tribe with completion work to deliver water to Dry Prairie
Rocky Boy's/North Central Montana Rural Water System (Montana)	Assist the Chippewa Cree Tribe of the Rocky Boy's Indian Reservation to complete major portions of its new water system and three areas of the North Central Montana Rural Water System.

Finally, Reclamation also coordinates with the U.S. Geological Survey (USGS) Water Availability and Use Science Program to understand groundwater availability in the West. In the Missouri River Basin, there is one completed groundwater assessment and one planned:

- The High Plains Aquifer study quantified current groundwater resources, evaluated changes in those resources over time, and provided tools to forecast how those resources respond to stresses from future human and environmental uses. The improved quantitative understanding of the basin's water balance provided by this USGS study not only provided key information about water quantity but also is a fundamental basis for many analyses of water quality and ecosystem health.
- In addition to the High Plains Aquifer study, the development of two nationally important energy-producing areas, the Williston Basin (containing the Bakken Formation) and Powder River Basin, provide a critical opportunity to study the water-energy nexus within a groundwater context. Large amounts of water are needed for energy development in the Williston and Powder River Basins and this area is the focus of a USGS groundwater availability study that will:
  - quantify current groundwater resources in this aquifer system,
  - evaluate how these resources have changed over time, and
  - provide tools to better understand system response to future anthropogenic demands and environmental stress.

The aquifers in the regional system are the shallowest, most accessible, and in some cases, the only potable aquifers within the Northern Great Plains.

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