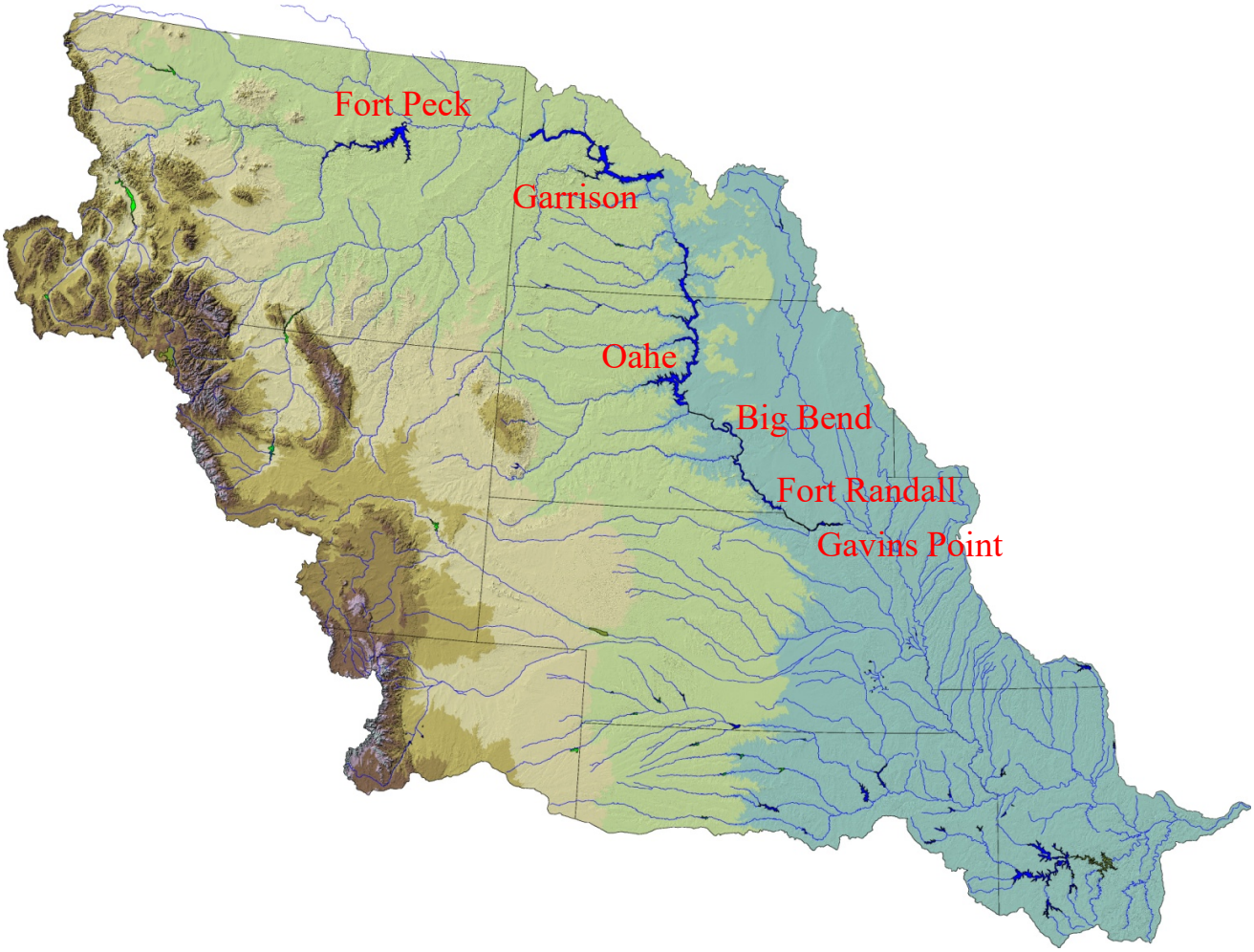
US Army Corps of Engineers ®
Northwestern Division

Missouri River Mainstem Reservoir System

System Description and Regulation

Missouri River Basin



Missouri River Basin Water Management Division
U.S. Army Corps of Engineers
Northwestern Division – Missouri River Basin
Omaha, Nebraska

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MISSOURI RIVER MAINSTEM RESERVOIR SYSTEM

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ABBREVIATIONS

AOP	-	annual operating plan
ACHP	-	Advisory Council on Historic Preservation
BiOp	-	Biological Opinion
BSNP	-	Bank Stabilization and Navigation Project
cfs	-	cubic feet per second
Corps	-	Corps of Engineers
CY	-	calendar year (January 1 to December 31)
elev	-	elevation
EOM	-	end of month
ESA	-	Endangered Species Act
°F	-	degrees Fahrenheit
KAF	-	1,000 acre-feet
kcfs	-	1,000 cubic feet per second
kW	-	kilowatt
kWh	-	kilowatt hour
Master Manual	-	Missouri River Mainstem Reservoir System Master Water Control Manual
MAF	-	million acre-feet
MRBWMD	-	Missouri River Basin Water Management Division
MRRMP-EIS	-	Missouri River Recovery Management Plan and Environmental Impact Statement
MW	-	megawatt
NAVD88	-	North American Vertical Datum of 1988
NPDES	-	National Pollutant Discharge Elimination System
ppm	-	parts per million
PA	-	Programmatic Agreement
P.L.	-	public law
P-S MBP	-	Pick-Sloan Missouri Basin Program
RPA	-	Reasonable and Prudent Alternative
System	-	Missouri River Mainstem Reservoir System
SHPO	-	State Historic Preservation Officers
SPP	-	Southwest Power Pool
SR-FTT	-	Steady Release – Flow-to-Target
T&E	-	Threatened and Endangered
THPO	-	Tribal Historic Preservation Officers
USBR	-	United States Bureau of Reclamation
USFWS	-	United States Fish and Wildlife Service
USGS	-	United States Geological Survey
Western	-	Western Area Power Administration

DEFINITION OF TERMS

Acre-foot (AF, ac-ft) is the quantity of water required to cover 1 acre to a depth of 1 foot and is equivalent to 43,560 cubic feet or 325,850 gallons.

Cubic foot per second (cfs) is the rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second and is equivalent to approximately 7.48 gallons per second or 448.8 gallons per minute. The volume of water represented by a flow of 1 cubic foot per second for 24 hours is equivalent to 86,400 cubic feet, approximately 1.983 acre-feet, or 646,272 gallons.

Discharge is the volume of water (or more broadly, volume of fluid plus suspended sediment) that passes a given point within a given period of time.

Drainage area of a stream at a specific location is that area, measured in a horizontal plane, enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into the river above the specified point. Figures of drainage area given herein include all closed basins, or noncontributing areas, within the area unless otherwise noted.

Drainage basin is a part of the surface of the earth that is occupied by drainage system, which consists of a surface stream or body of impounded surface water together with all tributary surface streams and bodies of impounded water.

Gaging station is a particular site on a stream, canal, lake, or reservoir where systematic observations of hydrologic data are obtained.

Runoff in inches shows the depth to which the drainage area would be covered if all the runoff for a given time period were uniformly distributed on it.

Streamflow is the discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

Storage is the amount of water stored in the System or in any individual reservoir project at a given time.

Storage capacity is the volume of water that can be stored in the System or any individual reservoir project.

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MISSOURI RIVER MAINSTEM RESERVOIR SYSTEM

System Description and Regulation

I. FOREWORD

This report presents a summary of pertinent data and a description of the Missouri River Mainstem Reservoir System (System) and discusses the regulation of the System to serve the Congressionally authorized project purposes. The Missouri River Basin Water Management Division (MRBWMD), located in Omaha, Nebraska, directs the regulation of the System to serve the Congressionally authorized project purposes of flood control, navigation, hydropower generation, irrigation, water supply, water quality control, recreation, and fish and wildlife. In addition, operation of the System must also comply with other applicable federal statutory and regulatory requirements. The combined storage capacity of the six mainstem dams, 72.4 million acre-feet (MAF), makes it the largest reservoir system in North America. The System is regulated using guidelines published in the Missouri River Mainstem Reservoir System Master Water Control Manual (Master Manual). The Master Manual presents a highly technical description of the water control plan and operational objectives for the integrated regulation of the System. The purpose of this document is to provide an abbreviated discussion of the regulation of the System under the Master Manual guidelines. In the event substantive differences exist between this document and the Master Manual, the Master Manual takes precedence unless specifically noted.

The Master Manual, which was first published in 1960 and subsequently revised during the 1970s and in 2004/2006, was last revised in 2018. In the March 2004 revision, the Master Manual included more stringent drought conservation measures. The March 2006 revision included technical criteria for a spring pulse from Gavins Point Dam to benefit endangered species. System regulation must consider impacts on the three threatened and endangered (T&E) species protected under the Endangered Species Act (ESA): the endangered interior least tern, the threatened piping plover, and the endangered pallid sturgeon. The 2004 revision of the Master Manual represented the culmination of a review that began in 1989 during the first major drought the Missouri River basin experienced since the System first filled in 1967.

The current Master Manual was completed in 2018, based on the 2018 Missouri River Recovery Management Plan and Environmental Impact Statement (MRRMP-EIS). As part of the Master Manual revision, the bimodal spring pulse from Gavins Point Dam and reservoir unbalancing were removed. The 2018 Master Manual is located on the NWD website: http://www.nwd-mr.usace.army.mil/rcc/MasterManual.html. A summary of the changes from the 2004/2006 Master Manual to the 2018 Master Manual is also located on the NWD website: https://www.nwd.usace.army.mil/Media/Fact-Sheets/Fact-Sheet-Article-View/Article/1704769/missouri-mainstem-master-manual/.

An Annual Operating Plan (AOP) is developed each year that presents simulations of the System regulation for the upcoming year to serve the authorized purposes under varying hydrologic conditions. Every fall, a draft AOP is prepared by the MRBWMD and made available for public review. Generally, the draft AOP is posted on the MRBWMD website by

early October and comments are accepted through mid-November. Public meetings, typically held at five or six locations throughout the Missouri River basin, are usually conducted in mid- to late October, and, after consideration of Tribal and public comments, the final AOP is posted on the MRBWMD website (www.nwd-mr.usace.army.mil/rcc/) in late December. Spring public meetings, typically held at five or six locations throughout the Missouri River basin usually in mid-April, are conducted to provide an update on the current hydrologic conditions and projected System regulation for the remainder of the year as it relates to implementing the final AOP.

Regulation plans developed in the AOP will likely require real-time adjustments to respond to substantial departures from expected runoff; to address emergencies, including short-term intrasystem adjustments to protect human health and safety; to prevent loss of historic and cultural properties; or to meet the provisions of applicable laws, including the ESA. These adjustments would be made, to the extent possible, after evaluating impacts to other System uses, would generally be short-term in nature, and would continue only until the issue is resolved.

Under the terms of Stipulation 18 of the March 2004 "Programmatic Agreement for the Operation and Management of the Missouri River Main Stem System for Compliance with the National Historic Preservation Act, as amended" (PA), the Corps agreed to consult/meet with the affected Tribes and Tribal Historic Preservation Officers (THPO), State Historic Preservation Officers (SHPO), the Advisory Council on Historic Preservation (ACHP), and other parties regarding the draft AOP. The purpose of this consultation/meeting is to determine whether operational changes are likely to result in changes to the nature, location, or severity of adverse effects to historic properties or to the types of historic properties affected and whether amendments to the Corps' Cultural Resources Management Plans and Five-Year Plan are warranted to better address such effects to historic properties.

II. DESCRIPTION OF MISSOURI RIVER BASIN AND MISSOURI RIVER

A. Basin Geography

The Missouri River basin has a total drainage area of 529,350 square miles, including about 9,700 square miles located in Canada. The portion of the basin within the United States extends over one-sixth of the Nation's area, exclusive of Alaska and Hawaii. It includes all of Nebraska; most of Montana, Wyoming, North Dakota and South Dakota; about half of Kansas and Missouri; and smaller parts of Iowa, Colorado and Minnesota. The Missouri River is the longest river in North America extending 2,321 miles from Three Forks, Montana to the mouth near St. Louis, Missouri, and 2,619 miles from its utmost source at Hell Roaring Creek to the mouth. A map of the Missouri River basin identifying the major mainstem and tributary Corps civil works projects and certain U.S. Bureau of Reclamation (USBR) projects is shown on **Plate 1**. A summary of engineering data for the six mainstem projects is shown on **Plate 2**. **Figure 1** shows a profile of the mainstem projects, including the elevations of the projects at their respective bases of Annual Flood Control and Multiple Use Zones and locations in river miles above the mouth of the Missouri River near St. Louis. **Figure 2** displays the relative proportion of storage capacity in each of the projects.

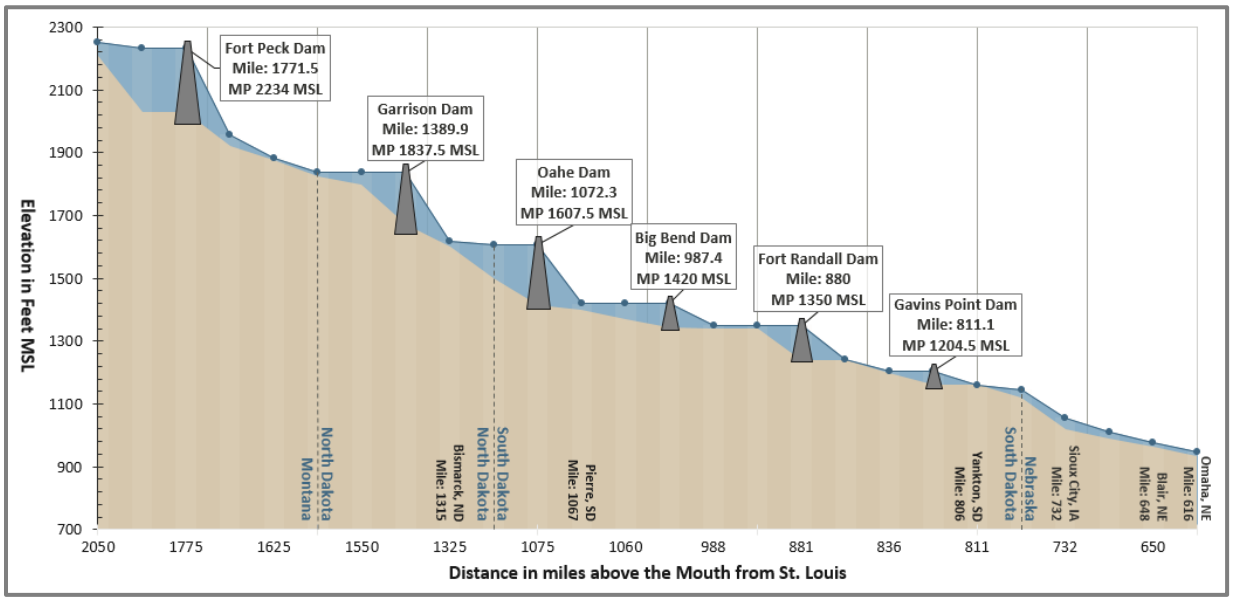
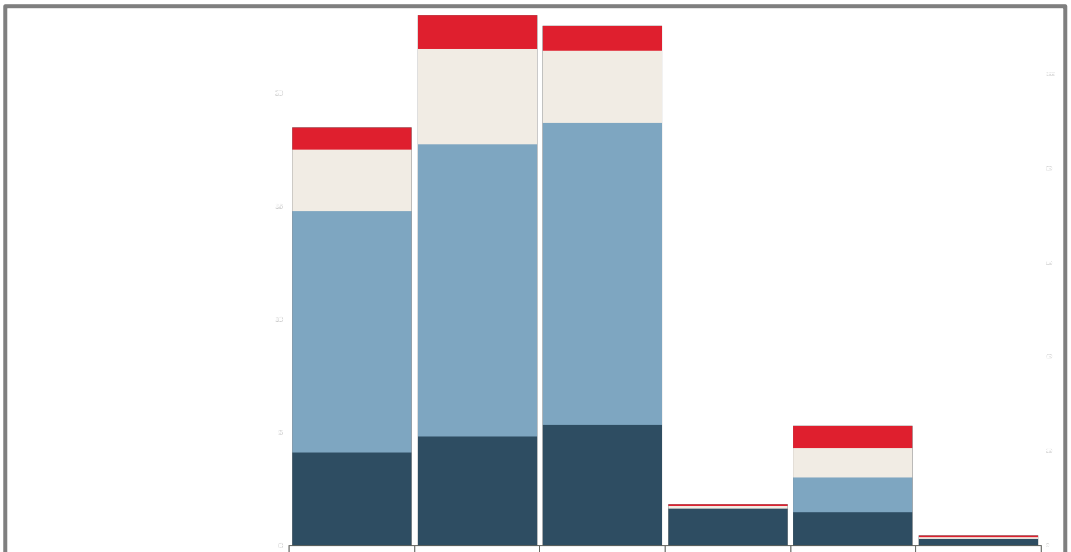


Figure 1. Profile of Missouri River Mainstem Reservoir System.



	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
Exclusive Flood	0.971	1.495	1.107	0.061	0.986	0.054
Annual Flood	2.704	4.211	3.208	0.118	1.306	0.079
Carryover	10.7	12.951	13.353		1.532	
Permanent	4.088	4.794	5.315	1.631	1.469	0.295
Gross Storage in MAF	18.463	23.451	22.983	1.81	5.293	0.428
72.4 MAF System Storage	26%	32%	32%	2%	7%	1%
Accumulative %	26	58	90	92	99	100

Figure 2. Missouri River Mainstem Reservoir System – Storage Capacities.

Basin topography varies from the 56,000-square-mile Rocky Mountain area in the West where many peaks exceed 14,000 feet (NAVD88) in elevation, to the approximately 370,000-square-mile Great Plains area in the heartland of the basin, to the 90,000-square-mile Central Lowlands in the lower basin where the elevation is approximately 450 feet (NAVD88) near the mouth at St. Louis, Missouri. The Black Hills in South Dakota and the Ozarks in Missouri are isolated domelike uplifts that have been eroded into a hilly and mountainous topography. Stream slopes vary from about 200 feet per mile in the Rockies to an average of one foot per mile along the Missouri River as it flows through the Great Plains and Central Lowlands.

Several major Missouri River tributaries are shown on **Plate 1:** the Yellowstone River, which drains an area of over 70,000 square miles, and joins the Missouri River near the Montana-North Dakota boundary; the Platte River, which drains an area of approximately 90,000 square miles, and enters the Missouri River in eastern Nebraska; and the Kansas River, which empties into the Missouri River in eastern Kansas and drains an area of approximately 60,000 square miles. A prominent feature in the drainage pattern of the upper portion of the basin is that every major tributary, with the exception of the Milk River, is a right bank tributary flowing to the east or to the northeast. Only in the lower basin below Gavins Point Dam is a fair balance reached between left and right bank major tributaries. The direction of flow of the major tributaries is of particular importance from the standpoint of potential concentration of flows from storms that typically move across the basin in an easterly direction. It is also important in another respect on the Yellowstone River, since early spring temperatures in the headwaters of the Yellowstone River and its tributaries are normally from 8 to 12 degrees Fahrenheit (°F) higher than along the northern most reach of the Missouri near the Yellowstone confluence. This ordinarily results in ice breakup on the Yellowstone River prior to the time the ice goes out of the Missouri River, thereby contributing to ice jam floods along the Missouri River downstream from its confluence to near Williston, North Dakota.

B. <u>Climatology</u>

The Missouri River basin's broad range in latitude, longitude and elevation and its location near the geographical center of the North American continent result in a wide variation in climatic conditions. The climate of the basin is produced largely by interactions of three great air masses that have their origins over the Gulf of Mexico, the northern Pacific Ocean, and the northern Polar Regions. These air masses regularly traverse the basin throughout the year. The Gulf air mass tends to dominate the weather in summer and the Pacific and Polar air masses during the winter. This seasonal domination by the air masses and the frontal activity caused by their collisions produce the general weather regimens in the basin. As is typical of a continental-interior plains area, the variations from normal climatic conditions, from season to season and from year to year, are very great. Several extreme events have occurred in the period of record, from the severe plains area drought of the 1930s when above-average summer temperatures and below-average precipitation prevailed for more than a decade, to a high mountain snowpack with periods of heavy spring rainfall resulting in record flooding for numerous rivers across the basin in 2011.

Average annual precipitation ranges from as low as 8 to 10 inches just east of the Rocky Mountains to more than 40 inches in the southeastern part of the basin and in parts of the Rocky

Mountains. Prolonged droughts of several years' duration and frequent shorter periods of deficient moisture, interspersed with periods of abundant precipitation, are characteristic of the Great Plains. The combination of moderate cyclonic activity and increased air mass moisture content that occurs during the spring and early summer months results in the normal seasonal precipitation maximum being observed through the basin during that time. Precipitation during the summer and late fall months is usually of the short-duration thunderstorm type with small centers of high intensity. However, widespread general rains will occasionally occur, especially in the lower basin. Winter precipitation generally occurs in the form of snow in the northern and central portions of the basin; however it may occur in the lower basin as either rain or snow or a mixture of both. Average annual snowfall ranges from 12 inches in the lower basin to more than 36 inches in North Dakota and to more than 48 inches in the high plains areas in the west. High elevation stations in the Black Hills and in the Rockies along the western edge of the basin receive in excess of 72 inches of snowfall in many years. By late May, snow depths of up to 6 feet, with a water equivalent of 2 feet, are not uncommon at mountain locations. Snow does not usually progressively accumulate over the central plains, but is melted by intervening thaws. The northern plains, however, has accumulated snow into the spring, especially when snow that accumulated on the ground by the end of winter had a water equivalent of 3 inches or more in the season.

Due to its mid-continent location, the basin experiences temperatures noted for wide fluctuations and extremes. Winters are relatively cloudy and cold over much of the basin, while summers are fairly hot. Spring is normally cool, humid and windy, while autumn is normally cool and dry. Temperature extremes in the basin range from winter lows of near -50°F to summer highs of near 115°F. Parts of the basin regularly experience maximum temperatures above 100°F in the summer and minimums below -25°F.

C. Water Supply

Records of monthly flows and their distribution above Sioux City, Iowa are available for the period 1898 to date. During planning studies of the System in the 1940s, extension of the Missouri River discharge data prior to 1928 was considered to be essential. Accordingly, comprehensive studies were made and monthly streamflow data developed for selected stations through the period extending from 1898 to the initiation of the expanded streamflow measurement program that began in 1928. Because water use for all purposes has expanded significantly since settlement of the basin first began, adjustment of the records to represent a common level of water resource development was also considered necessary so that the flow data would be directly comparable from year to year. While any development level would have been satisfactory, the 1949 level was selected because it was just before the accelerated water resource development that occurred in the Missouri River basin during the 1950s. Records accumulated since then have also been adjusted to the 1949 level for comparability purposes.

1. Runoff. About one-fourth of the annual water supply above Sioux City, Iowa is received in the months of March and April as a result of plains snowmelt augmented by early spring rains. Roughly half of the annual runoff comes in the months of May, June and July as a result of the melt of the mountain snowpack augmented by late spring and summer rains. Runoff varies widely from year to year but averages 25.8 MAF annually above Sioux City (1898-2019).

Records dating back to 1898 indicate runoff has varied from a high of 61.0 MAF in 2011 to a low of 10.7 MAF in 1931. In this 120-plus year period, the basin has experienced four periods of significant drought, including the record 12-year drought from 1930 to 1941, the 8-year drought from 1954 to 1961, the 6-year drought that began in 1987 and ended abruptly with the flood of 1993, and the most recent 8-year drought that began in 2000 and ended in 2007. During the 2000-2007 drought, the System storage reached its historic low of 33.9 MAF, which made it the longest and most impactful drought since the System first filled in 1967.

The MRBWM office uses the upper basin HEC-ResSim model to conduct the AOP studies. The AOP study period is 19 months, starting on August 1 of Year 0 (current year) and extending to the end-of-month (EOM) February of Year 2. The AOP studies are prepared on August 1 with initial conditions based on Year 0: EOM July reservoir elevations/storages, the remaining five months of the calendar year runoff forecast and current year's monthly depletion estimates.

The AOP studies reflect statistically-derived runoff based on the 122-year historical record of runoff above Sioux City, Iowa during the period 1898-2019. Five runoff levels with statistical significance (implied by their titles) are used in the AOP studies: upper decile, upper quartile, median, lower quartile and lower decile. These runoff levels encompass 80 percent of the historic runoff (lower decile to upper decile).

Two additional runoff volume scenarios are available, the 2 and 98 percent non-exceedances, that encompasses 96 percent of the historic runoff records. Both have a 1 in 50 chance of occurring. Neither of these "2 percent" runoff volumes are included in the AOP study scenarios, but could be implemented for any given runoff season should the runoff forecast exceed the upper decile runoff scenario or be less than the lower decile runoff scenario. All the runoff volumes for the AOP studies are adjusted to 1949 level of water resources development in the Missouri River basin.

2. <u>Upstream Effects</u>. Not all of the runoff from the drainage basin is available for storage in the reservoirs or release for downstream purposes. Some is lost by evaporation, some is intercepted and depleted for agricultural, municipal or industrial uses, and some runoff is regulated by upstream reservoirs.

a. <u>Evaporation Losses</u>. The System reservoir evaporation losses vary in magnitude and are calculated as the net losses that occur when precipitation on the reservoir surface is considered. Since there is a great variation in precipitation from year to year and the surface area of a particular project at its maximum operating level can be more than double the surface area at minimum pool levels, these losses may vary widely from day to day and year to year. In general, the sum of evaporation losses at the six projects has averaged approximately 3 MAF per year. In accounting for past regulation, evaporation losses are based on observed conditions at the projects and are dependent on the actual surface area of the reservoirs and prevailing weather conditions. The amount of evaporation used for forecasted regulation of the System is based on average meteorological conditions and the forecasted variations in surface area of the reservoirs.

b. Depletions. As mentioned previously, the year 1949 is the base level of development against which changes from the natural water supply are estimated. In comprehensive basin planning studies, the U.S. Bureau of Reclamation (USBR), in cooperation with other interested Federal and state agencies in the basin, has made detailed investigations of the various developments that affect the natural streamflow within the basin. Some of these developments deplete water, others accrete water, while others merely rearrange the natural supply. These developments include surface water irrigation, ground water irrigation and its effects on surface water supplies, municipal and industrial supplies, watershed treatment, rural domestic and livestock uses, tributary reservoirs, recreation lakes and stock ponds, evaporation from man-made ponds and reservoirs, and forestry practices. The USBR also makes estimates of future levels of depletions based on projections of water uses along the System. The Corps uses the USBR projections and actual depletions in their forecasting and planning for System regulation.

c. Upstream Reservoirs. Regulation of the streamflow by the upstream tributary reservoirs affects the regulation of the System. The most significant upstream projects are the USBR's Clark Canyon, Canyon Ferry and Tiber reservoirs above Fort Peck, and Boysen and Yellowtail reservoirs above Garrison. Their regulation may increase or decrease inflows to the downstream System reservoirs over an extended period. The influence of these projects on the System during the year ahead is estimated from forecasts provided by the USBR. The extent of tributary reservoir impacts depends on current System storage and the magnitude of the water supply.

D. Mainstem and Tributary Streamflow Characteristics

Streams originating from the Rocky Mountains are fed by snowmelt, are clear flowing, have steep gradients, and have cobble-lined channels. Stream valleys often are narrow in the mountains and widen out as they emerge from the mountains onto the out-wash plains. Mean annual runoff in terms of precipitation depth from the mountainous areas is high, exceeding 20 inches in some areas along the Continental Divide. Flood flows in this area are generally associated with the mountain snowmelt period occurring in May and June. Occasionally, summer rainfall floods with high, sharp peaks occur in the foothills areas.

Streams flowing across the plains areas of Montana, Wyoming and Colorado have variable characteristics. The larger streams with tributaries originating in the mountain areas carry sustained spring and summer flows from mountain snowmelt and have moderately broad alluvial valleys. Streams originating locally often are wide and sandy-bottomed, experience intermittent flows, and are subject to high-peak rainfall floods.

Streams in the plains region of the Dakotas, Nebraska and Kansas, with the exception of the Nebraska Sandhills area, generally have flat gradients and broad valleys. Except for the Platte River, most of the streams originate in the area and are fed by plains snowmelt in the early spring and occasional rainfall runoff throughout the warm season. Streamflow is variable. Stream channels are small for the size of the drainage areas involved and the flood potentials are high. When major rainstorms occur in the tributary areas, streams are forced out of their banks onto the broad floodplains.

Streams in the region east of the Missouri River have variable characteristics. Those in the Dakotas, such as the Big Sioux and James Rivers, are meandering streams with extremely flat gradients and very small channel capacities in relation to the areas drained. Drainage areas generally are covered with glacial drift, are extremely flat, and contain many pothole lakes and marshes. Rainfall in the spring often combines with the annual plains snowmelt to produce floods that exceed channel capacities and spread onto the broad floodplains.

Streams in the Ozark Highlands of Missouri resemble mountain streams with their clear, dependable base flows. Much of the area is underlain by limestone and contains cavernous underground springs. The hilly terrain produces high-peak runoff, which contributes to frequent high-peak floods of large volume.

Many instances of above-bankfull flows were experienced through the reach from Fort Peck to the Platte-Missouri River confluence below Omaha, Nebraska prior to System regulation. Since regulation of the System commenced, there would have been many more flood occurrences were it not for the upstream regulation. Regulation provided by the System, augmented by upstream tributary reservoir storage, has greatly reduced significant flood flows on the Missouri River in this reach. Still, the System has not created a flood-free zone along the Missouri River for all conditions. Downstream of the Platte-Missouri River confluence, the incremental drainage area is of sufficient size that above-bankfull Missouri River stages can continue to be expected. This is primarily a result of runoff from major storms over the unregulated tributary watershed areas downstream of the System.

III. MAINSTEM RESERVOIR SYSTEM

A. System Description

The System is comprised of six dams and reservoirs that were constructed by the Corps. The System controls runoff of the basin's upper half. The six dams, from the upper three larger dams of Fort Peck in eastern Montana, Garrison in central North Dakota and Oahe in central South Dakota, to the lower three smaller dams of Big Bend and Fort Randall in South Dakota, and Gavins Point along the Nebraska-South Dakota border, comprise the largest reservoir system in the United States. Four of the System reservoirs were named by Congress: Lake Sakakawea (Garrison Dam); Lake Sharpe (Big Bend Dam); Lake Francis Case (Fort Randall Dam); and Lewis and Clark Lake (Gavins Point Dam).

The combined storage capacity of all six System reservoirs is 72.4 MAF, about three times the annual runoff into the System above Sioux City, Iowa (3:1). This high ratio of storage capacity to runoff lends an unusual degree of flexibility to the regulation of the multi-purpose reservoir system. In contrast, the ratio of reservoir storage capacity to annual runoff in the Columbia and Ohio River basins is 1:5, approximately one acre-foot of storage for each five acre-feet of annual runoff.

The storage capacity of the six individual reservoirs ranges from over 23 MAF at Garrison and Oahe, to less than 0.5 MAF at Gavins Point as shown in **Table 1**. The System is also unique in the fact that nearly 90 percent of the combined storage capacity is in the upper three reservoirs of Fort Peck, Garrison and Oahe. As a result, these three projects experience the bulk of the impacts during periods of very high runoff or extended drought. The lower three projects, Big Bend, Fort Randall and Gavins Point, are regulated in much the same manner year after year regardless of the runoff conditions.

Table 1
Reservoir Storage Capacities (in MAF)

Project	Storage Capacity
Fort Peck	18.463
Garrison	23.451
Oahe	22.983
Big Bend	1.810
Fort Randall	5.293
Gavins Point	0.428
Total	**72.428**

The System storage capacity is divided into four unique storage zones for regulation purposes, as shown in **Figure 3**. Information on the unique storage zones for each of the six individual reservoirs is provided on **Table 2**. Other pertinent data for all projects are presented in the Summary of Engineering Data shown on **Plate 2**. The bottom 24 percent of the total System storage capacity comprises the Permanent Pool Zone, which was designed for sediment storage, minimum fisheries, and minimum hydropower heads. The largest zone, comprising 53 percent of the total storage capacity, is the Carryover Multiple Use Zone, which is designed to serve all project purposes, though at reduced levels, through a severe drought like that of the 1930s.

The Annual Flood Control and Multiple Use Zone, occupying 16 percent of the total storage capacity, is the desired operating zone of the System. Ideally the System is at the base of this zone at the start of the spring runoff season. Spring and summer runoff is captured in this zone and then metered out throughout the remainder of the year to serve the other project purposes, returning the reservoirs to the base of this zone by the start of the next runoff season.

The top 7 percent of the System storage capacity is the Exclusive Flood Control Zone. This zone is used only during extreme floods, and evacuation is initiated as soon as downstream conditions permit. When there is water in this zone, regulation decisions are made exclusively for the flood control purpose.

Table 2
Reservoir Storage Zones
(Storage in MAF, Elevations in feet)

	Top of Permanent		Top of Carryover Multiple Use		Top of Flood Control & Multiple Use		Top of Exclusive Flood Control	
Project	**Storage**	**Elevation**	**Storage**	**Elevation**	**Storage**	**Elevation**	**Storage**	**Elevation**
Fort Peck	4.1	2160.0	14.8	2234.0	17.5	2246.0	18.5	2250.0
Garrison	4.8	1775.0	17.7	1837.5	22.0	1850.0	23.4	1854.0
Oahe	5.3	1540.0	18.7	1607.5	21.9	1617.0	23.0	1620.0
Big Bend	1.6	1420.0	1.6	1420.0	1.7	1422.0	1.8	1423.0
Fort Randall	1.5	1320.0	3.0	1350.0	4.3	1365.0	5.3	1375.0
Gavins Point	0.3	1204.5	0.3	1204.5	0.4	1208.0	0.4	1210.0
System	**17.6**		**56.1**		**67.7***		**72.4**	

*Total storage is 67.7 MAF, individual storage values reflect rounded values.

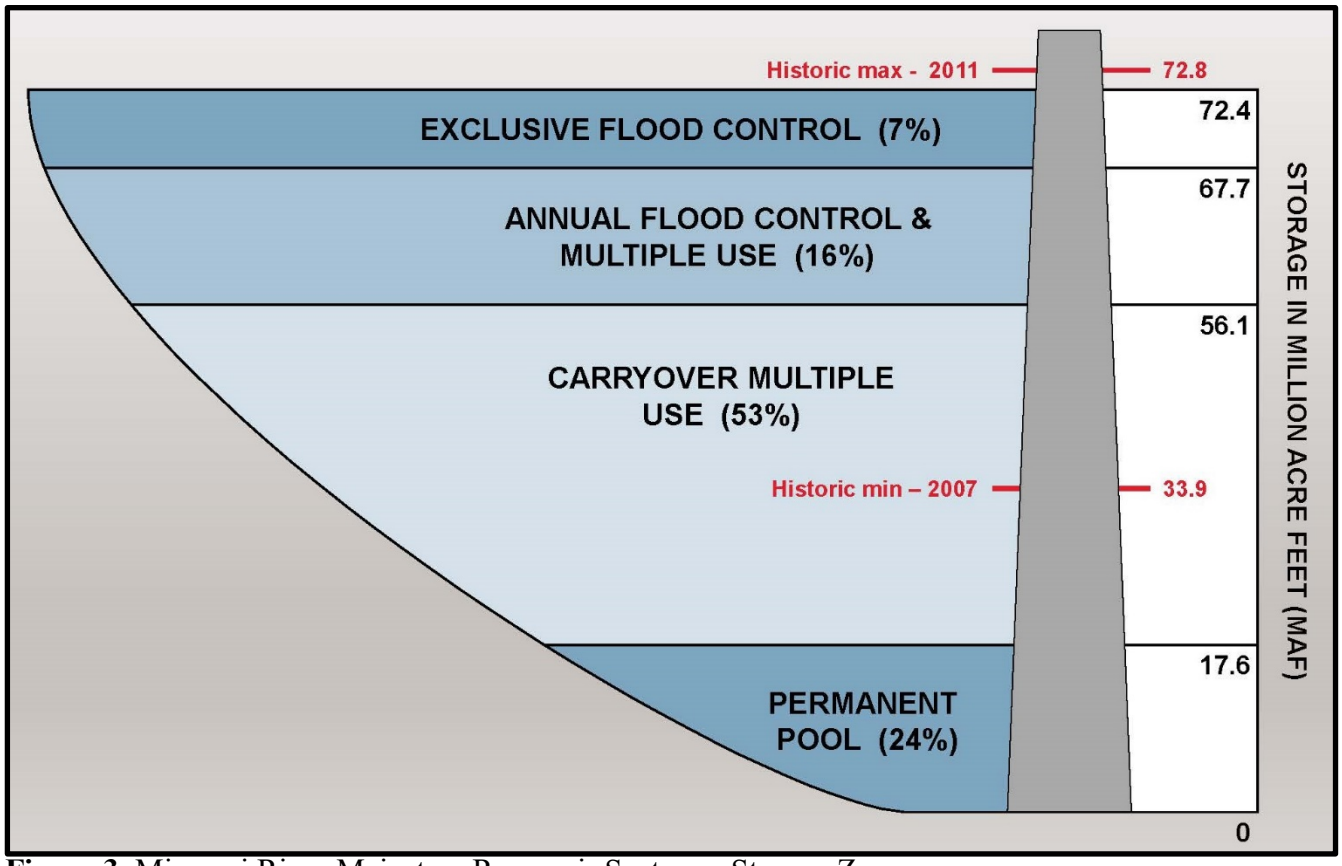


Figure 3. Missouri River Mainstem Reservoir System – Storage Zones.

B. System Regulation

1. Overview. The System is regulated to serve the Congressionally authorized purposes of flood control, navigation, hydropower, irrigation, water supply, water quality control, recreation and fish and wildlife. Overall System regulation follows the water control plan presented in Chapter VII of the Master Manual. Each of the six System projects also has an individual water control manual that presents more detailed information on its regulation.

System regulation is, in many ways, a repetitive annual cycle. During the March-July period, spring rainfall and snowmelt from the melting of plains and mountain snow produces much of the year's runoff into the System. After reaching a storage peak, usually during July, the amount of water stored in the System declines as releases are made to meet authorized purposes during the drier summer, fall and winter months. During the late fall and winter, the mountain and plains snowpack begins to accumulate and the cycle begins again. A similar pattern may be found in rates of releases from the System, with the higher levels of flow from mid-March to late November, followed by low rates of winter release from late November until mid-March, after which the cycle repeats. The Water Control Calendar of Events, shown as **Figure 4**, presents the time sequence of many of these cyclic events.

The water control plan is designed to achieve the multi-purpose objectives of the System given these cyclical events. As shown on **Figure 4**, the two primary high-risk flood seasons shown are the plains snowmelt season, which extends from late February through April, and the mountain snowmelt period, which extends from May through July. Runoff during both of these periods may be augmented by rainfall. The winter ice-jam flood period extends from mid-December through February. Releases are made from the projects at all times throughout the entire year, with Big Bend being the lone exception. The releases meet downstream authorized purposes including, but not limited to, hydropower generation, navigation flow support, water supply, water quality control and recreation. The highest average power generation period extends from mid-April to mid-October, with high peaking loads during the winter heating season (mid-December to mid-February) and the summer air conditioning season (mid-June to mid-August). The major maintenance periods for the System hydropower facilities extend from March through mid-May and September through November, which normally are the lower demand and off-peak energy periods. The exception is Gavins Point; maintenance is performed after the end of the navigation season when all three generation units are not normally required to provide downstream flow support. The normal 8-month navigation season extends from April 1 through November 30 at the mouth. During the navigation season System releases are scheduled, in combination with downstream tributary flows, to meet downstream target flows. Winter releases after the close of navigation season are much lower, and vary depending on the need to conserve or evacuate System storage while managing downstream river stages for water supply given ice conditions. Minimum release restrictions and pool fluctuations for fish spawning management generally occur from April through June. Nesting of the two federally protected bird species, the endangered interior least tern and the threatened piping plover, occurs from early May through mid-August.

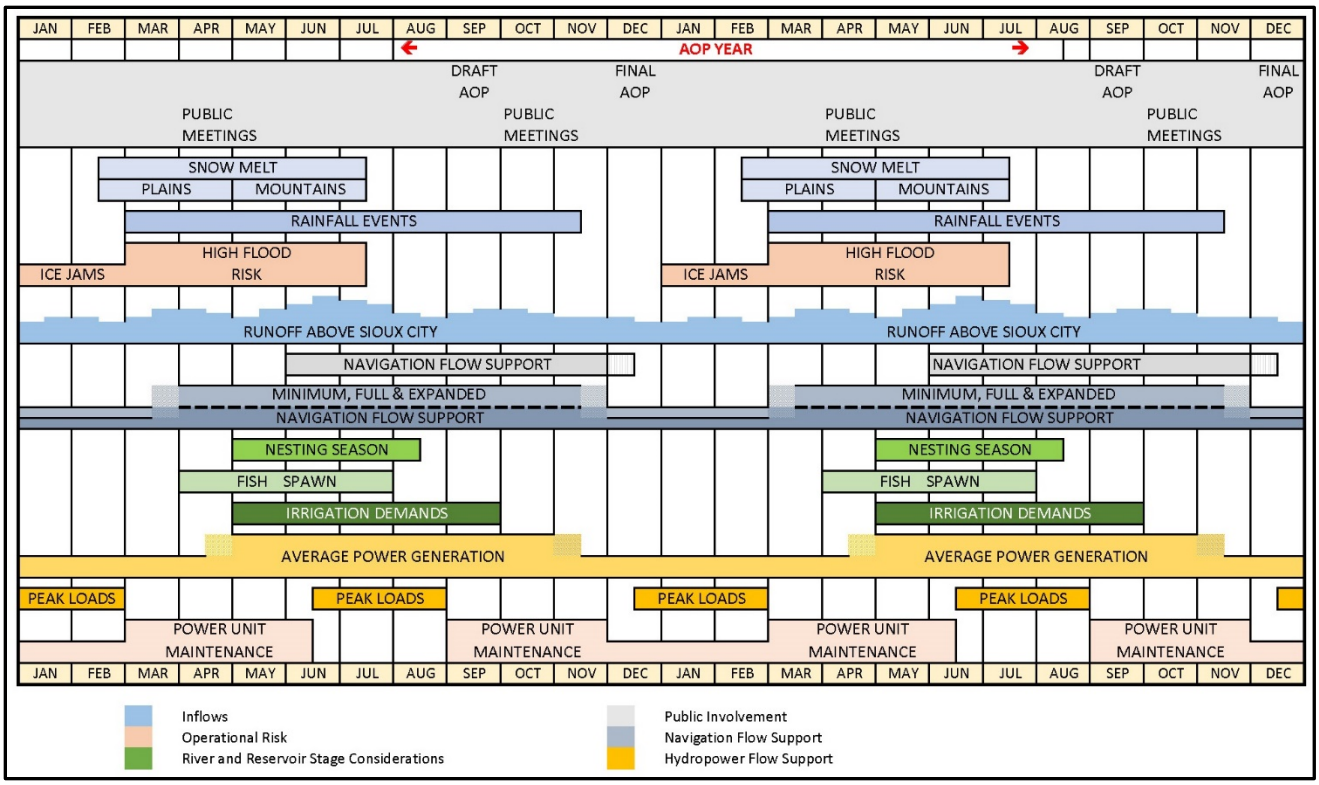


Figure 4. Water Control Calendar of Events.

2. <u>Intrasystem Regulation - General</u>. Much of the flexibility of the System is derived from intrasystem regulation, or the transfer of water from one reservoir to another. System releases necessary to support downstream water requirements are defined within a relatively narrow range. Inflow into the uppermost Fort Peck project is from tributary flows in the headwaters area. The majority of inflow into Garrison is from a combination of Fort Peck releases and the Yellowstone River basin, most of which is unregulated. While there is some incremental inflow in the reaches between the reservoirs, the majority of inflow to the lower four System reservoirs is subject to regulatory control from Fort Peck and Garrison.

Intrasystem regulation is an important tool in the management of water in the System to meet the authorized purposes. It is used to regulate individual reservoir levels in the System to balance or unbalance the water in storage at each project, to smooth the annual System regulation by forecasting the timing and volume of snowmelt runoff, to maintain the seasonal capability for hydropower generation, and to improve conditions for the reservoir fish spawn and recruitment. Intrasystem regulation is used to maintain stages on the open river reaches between projects at desirable levels. Release changes can be made to meet emergencies, including the protection of human health and safety, protection of significant historic and cultural properties, or to meet the provisions of applicable laws including the ESA. Release changes are made, to the extent reasonably possible, after evaluating impacts to other System uses, are generally short-term in nature, and continue only until the issue is resolved.

The presence of the upper three large reservoirs in the System increases intrasystem regulation flexibility. A small reservoir such as Gavins Point, which has total storage of less

than 500,000 acre-feet, can tolerate a large difference between inflow and release for less than a day. Big Bend is in this category as well. To a lesser extent, so is Fort Randall, although its storage capacity in its Carryover Multiple Use and Annual Flood Control and Multiple Use zones of nearly 3 MAF makes it possible for significant storage transfers and flow differentials extending a month or more. Nevertheless, it is the upper three large reservoirs of Fort Peck, Garrison and Oahe, with their combined 37.0 MAF of storage in their Carryover Multiple Use zones plus an additional combined 10.2 MAF of storage in their Annual Flood Control and Multiple Use zones, which provide the flexibility to adjust intrasystem regulation to better serve authorized purposes.

3. Seasonal Intrasystem Regulation Patterns. Factors that influence intrasystem regulation may vary widely from year to year; however, regulation of the System generally follows a regular seasonal pattern. Some of these factors, such as the amount of System storage and the magnitude and distribution of inflow received during the year, can affect the timing and magnitude of individual System project releases. The levels of each of the six System reservoirs are checked on a daily basis and compared to the water control plan and the AOP. Adjustments to the amount of water transferred between reservoirs are made, when necessary, to achieve the desired volume of water in each project and to maximize power generation.

a. Summer Release Patterns. Intrasystem regulation to meet the needs of power generation follows a regular seasonal cycle. Releases from Gavins Point are generally at their highest when providing flow support for navigation, as shown on Figure 3. Since Gavins Point reservoir is small, these releases must be backed up with similar magnitude releases from Fort Randall. Fort Randall, in turn, requires similar support flows from Oahe via Big Bend, a re-regulation project. At this point the chain can be interrupted, because Oahe is large enough to support high releases for extended periods without high inflows. During years when upper basin runoff is near average or below average, releases for hydropower generation at Fort Peck and Garrison are held to lower levels during the summer to allow more winter hydropower production. During above-average runoff years in the upper basin, flood control regulation, the evacuation of water accumulated in the flood control zones or the desire to balance or unbalance storage among the upper three projects, becomes an overriding consideration.

b. Winter Release Patterns. With the onset of the non-navigation season, conditions are reversed. Gavins Point releases are reduced to about one-third to slightly greater than half of summer levels, and the chain reaction proceeds upstream, curtailing daily average releases from Fort Randall, Big Bend and Oahe to lessen the chance of significant flood damages occurring from ice jams/blockages in downstream urban areas. During this period Fort Peck and Garrison daily releases are usually maintained at relatively high levels, albeit within the limits imposed by downstream ice conditions, to partially compensate for the reduction of hydropower generation from the lower four System projects.

c. Drawdown of Fort Randall Reservoir. An additional means of partially compensating for the reduced hydropower generation associated with the lower winter release rate from Gavins Point is the autumn drawdown of Fort Randall reservoir. In this regulation, releases from Oahe and Big Bend are reduced several weeks before the close of the navigation season. This leaves Fort Randall with the task of supplying a large portion of downstream flow

requirements for the remainder of the navigation season. The result is the evacuation of water stored in its Carryover Multiple Use Zone. This vacated storage space, otherwise referred to as "recapture storage capacity", in the Carryover Multiple Use Zone is then refilled with higher releases, and increased total hydropower generation, from Oahe and Big Bend during the non-navigation season.

The Fort Randall reservoir is normally drawn down from about 1355.0 to 1337.5 feet, which provides about 1.2 MAF of recapture storage capacity. During severe drought periods, the flexibility exists to draw down to elevation 1320.0 feet. This provides an additional recapture space of about 0.7 MAF and increases the average winter energy generation, per increased releases from Oahe and Big Bend, about 150 million kilowatt hours (kWh).

d. Recapture at Oahe. While not as significant (in terms of pool level fluctuation) as the drawdown and recapture regulation plan at Fort Randall reservoir, a similar recapture regulation plan at Oahe is coordinated with upstream Garrison and Fort Peck releases to significantly increase the amount of winter energy generation. Generally, during the 4-month winter period, Garrison releases, volume-wise, can be expected to be at least 1 MAF more (4,200 cfs/day for 120 days = 1.0 MAF) than Oahe releases. Recapture of these upstream releases generally results in a rise of about 5 feet or greater in the Oahe reservoir elevation during the winter months, depending on the current storage level and whether the upper three reservoirs are intentionally unbalanced.

4. Short-Term Intrasystem Adjustments. The interaction among projects previously described, repeated as it is year after year, might make intrasystem regulation appear to be a routine and rigid procedure. However, routine regulation is often disrupted by the short-term extremes of nature. Heavy rains may raise river stages near the flood level, necessitating a release reduction at one project and a corresponding increase at others. Very hot or very cold weather may create sharp increases in the demand for hydropower generation. Inflows for a week or for a season may concentrate disproportionately in one portion of the upper Basin, resulting in abrupt shifts in regulating objectives for individual System projects. In addition, short-term intrasystem adjustments are occasionally required to meet emergencies, including the protection of human health and safety, protection of significant historic and cultural properties, and/or to meet the provisions of applicable laws, including the ESA. These adjustments are made, to the extent possible, after evaluating impacts to other System uses, are generally short-term in nature, and continue only until the issue is resolved.

5. Project Release Limits. Limitations imposed on System regulation (maximums and minimums) are related not only to System or individual project storage, which is varied in accordance with the flood control restrictions previously given and the requirements for active storage pools, but also to releases.

a. Maximum Rates – Spring, Summer and Fall. During the spring, summer and fall, releases at all projects other than Gavins Point are normally within the powerplant discharge capacity, the river channel downstream usually being more than adequate to carry such releases. Discharges from all projects will usually be made through the powerplant to maximize hydropower generation. At times, providing flow support for downstream navigation may

require releases from Gavins Point in excess of powerplant capacity. At all projects, special regulation considerations may require releases bypassing the powerplants; however, this is expected to occur for only relatively short periods of time. Unusually large inflows during any particular year may require significant releases beyond those through the powerplants at any or all projects to evacuate flood waters and thereby maintain the future flood control capability of the System.

b. Maximum Rates - Winter. Releases are more restricted during the winter period. An ice cover can be expected to form over major portions of the Missouri River every winter and occasionally as far downstream as the river's mouth. During and after formation, this ice cover significantly reduces the discharge capacity of the river channel. In addition, during periods of ice formation and subsequent ice break-up, a substantial risk of ice jam formation and associated flooding exists. The maximum allowable winter releases are those that will not significantly increase the probability of flooding or intensify potential flooding during periods of ice cover. Downstream of the projects, releases may be limited during periods of ice formation and then gradually increased once a stable ice cover is in place. Once formed, the ice cover can be expected to remain through the winter. Downstream of Sioux City, ice formation or ice breakup can occur repeatedly throughout the season and may also jeopardize downstream navigation structures such as dikes and revetments. Since the travel time of any release from the System to areas of vulnerability is much longer than the time for which reliable forecasts of such events can be made, it is necessary to schedule winter System releases at a conservative level.

1) **Gavins Point.** During periods of normal or below water supply, winter releases from Gavins Point range from 12,000 to 17,000 cfs. During years with low winter releases, ice formation can result in significant stage reductions on the lower river; therefore, it is often prudent to increase Gavins Point releases prior to the onset of river ice build-up or even during a significant jam to maintain adequate stages at water intakes. Experience during recent years indicates that increasing Gavins Point releases speeds the recovery of the river to more normal stages and assures that the downstream water intakes are operational sooner or affected less by the icing conditions. The maximum daily winter release from Gavins Point usually ranges between 12,000 and 25,000 cfs. With an excess water supply and evacuation of flood control storage space as a primary consideration, a Gavins Point release rate may range from 25,000 and 30,000 cfs. The extent and location of river ice cover is important in determining the release rate. Experience accumulated during past winters indicates that at times it may be necessary to reduce System releases below these levels when bankfull to slightly above bankfull stages occur in the Nebraska City to St. Joseph reach of the Missouri River.

2) **Upper Five Projects**. No daily release limitations exist at Big Bend, where discharges are made almost directly into the downstream reservoir area. The maximum ice-covered channel capacity below Fort Peck and Garrison are estimated to be about 15,000 and 27,000 cfs, respectively, except during freeze-up. During freeze-up, releases are limited to lower levels until a stable ice cover is formed and the rough ice and streambed are smoothed sufficiently for the

channel to accommodate increased releases. Winter releases from Fort Randall are generally 1,000 to 2,000 cfs lower than those from Gavins Point, but during period of ice formation may be scheduled at or slightly higher than Gavins Point releases to prevent rapid declines in the Gavins Point pool elevation. At Oahe, peak hourly releases may be constrained to prevent urban flooding in the Pierre and Fort Pierre areas if severe ice conditions develop below the project.

c. Minimum Releases. There are no minimum daily flow requirements from Oahe or Big Bend except that, to the extent reasonably possible, weekend releases from Oahe during the spring, summer and fall are typically 3,000 cfs or higher during the daytime hours of the non-winter recreation season in the interest of downstream fishing and boating. In addition, during periods of ice formation a one-unit minimum may be imposed at Oahe to prevent ice formation in the channel directly below the dam. Minimum daily releases from Fort Peck and Fort Randall are typically maintained during the fish spawning seasons. Fort Peck also has a year-round instantaneous minimum release of 3,000 cfs for the trout fishery below the dam, though to the extent possible, releases are maintained above 4,000 cfs. During periods of high inflow below the project, releases may be scheduled below 3,000 cfs for flood damage reduction, but these instances are rare. Minimum daily releases at Fort Peck, Garrison, Fort Randall and Gavins Point are established as those necessary to supply water quality control and downstream water intake requirements, which generally also furnish more than an adequate quantity of water for irrigation withdrawals below the reservoirs. At Garrison, a minimum average daily release of 9,000 cfs has been established as a guide to provide for downstream intakes. Access problems have been experienced at municipal, industrial, powerplant and irrigation intakes along the length of the river due to channel degradation, inadequate intake screens, sandbar formation, winter ice formation, or relatively high elevation of the intakes. Temporary increases above the open-water minimum release rates may be made, to the extent reasonably possible, to allow intake owners to take remedial action. Maintaining access to water that is available in the river is the responsibility of the intake owner. All intake owners are encouraged to develop intake facilities that will operate through the full range of releases required for other project purposes.

d. Hourly Fluctuation of Release Rates. At all projects except Gavins Point, hourly release rates may vary widely as necessary to meet fluctuating power loads. Changes in release rates at Gavins Point are subject to limitations to restrict stage fluctuations downstream. Minimum hourly release restrictions are applicable at Fort Peck and Garrison due to downstream intakes. A uniform peaking release pattern has been established during the summer months at Garrison and Fort Randall for T&E nesting in the river below the projects, and may be reinstated at Fort Peck if T&E nesting patterns deem it necessary.

C. Sediment Investigations

Hydrographic resurveys, sediment sampling activities, and special studies of the System reservoirs and downstream reaches are planned and scheduled to meet the short-term and long-term needs related to sediment. A total of 690 sediment cross-section ranges for both aggradation and degradation reaches have been established and maintained since the projects were completed, as shown in **Table 3**. Each reservoir reach is surveyed periodically (10- to 25-year intervals) to update reservoir capacities, to assess the progress of aggradation and

degradation trends, to evaluate impacts of erosion or sedimentation on project functions, and to seek early solutions to problems in light of changing field conditions and goals. The frequency of reservoir surveys was established based on historic data and reservoir size. These regular reservoir surveys can be supplemented with reconnaissance inspections of major problem areas about once every five years. Intervening and/or partial resurveys may be conducted if warranted by a special study, or if findings from reconnaissance investigations reveal the need. High flood events are the most likely causes for these additional surveys.

Table 3
Hydrographic Survey Data

Project/Reach	Number of Cross Sections	Last Year Surveyed
Fort Peck – Fort Peck Lake	126	2007
Fort Peck Degradation Reach	45	2011
Garrison – Lake Sakakawea	136	2012
Garrison Degradation Reach	45	2012
Oahe – Lake Oahe	123	2012
Big Bend – Lake Sharpe	54	2012
Fort Randall – Lake Francis Case	27	2011
Fort Randall Degradation Reach	27	2011
Gavins Point – Lewis and Clark Lake	49	2011
Gavins Point Degradation Reach	42	2013
Total Cross Sections	690	

Table 4 summarizes the loss of System storage due to sediment deposition in the System reservoirs according to the latest information available. This table indicates a loss of 5.7 percent in total storage to the date of the last surveys with an annual sediment deposition rate of around 75,000 acre-feet. Sediment and hydrographic survey data collected, combined with hydrologic and hydraulic data in the System reservoirs, have been used extensively to investigate specific issues and concerns. Issues recently investigated include flooding and power constraints in the Bismarck-Mandan, North Dakota and Pierre, South Dakota areas; the raising of Highway 12 near Niobrara, Nebraska; claims for flooding damages on the Moreau, Cheyenne and Niobrara Rivers; downstream degradation impacts on tailwater and the powerplant operation below the Garrison, Fort Randall and Gavins Point Dams; Missouri River aggradation and degradation trends below Gavins Point Dam, and the effects of future depletions and sedimentation on System uses and resources.

Table 4
Sediment Depletion of Reservoirs
(in 1,000 Acre-Feet)

Project	Original Storage Capacity	Current	Capacity Loss (%)	Total Capacity Loss	Average Loss Rate (per year)
Fort Peck	19,557	18,463	5.6	1,094	17.2
Garrison	24,728	23,451	5.2	1,277	21.6
Oahe	23,571	22,983	2.5	588	14.8
Big Bend	1,980	1,810	8.6	170	3.4
Fort Randall	6,208	5,293	14.7	915	15.8
Gavins Point	575	428	25.6	147	2.7
Total	**76,799**	**72,428**	**5.7**	**4,371**	**75.5**

Three suspended-sediment sampling stations are presently in operation on major sediment producing tributaries and headwater areas of the System reservoirs to measure incoming sediment load. These include stations on the Yellowstone River at Sidney, Montana; the Bad River at Fort Pierre, South Dakota and the White River at Oacoma, South Dakota.

Downstream of Gavins Point Dam, six Missouri River suspended-sediment sampling stations are maintained at Sioux City, Iowa; Omaha, Nebraska; Nebraska City, Nebraska; St. Joseph, Missouri; Kansas City, Missouri; and Hermann, Missouri. Data from these stations provide continuous observation of sediment load changes used to analyze impacts of the System reservoirs and channelization below Sioux City on the downstream reach and to furnish vital information for the investigation of sediment-related problems and formulation of remedial measures. All sampling is conducted by the U.S. Geological Survey (USGS) under a cooperative streamgaging program, including the computation of sediment load records.

The accumulation of sediment in reservoir headwaters and at the mouths of sediment-laden tributaries has impacted project purposes by reducing channel capacity and raising water surfaces, in some instances by several feet. Areas of particular concern include Williston, North Dakota (Garrison headwaters); Bismarck, North Dakota (Oahe headwaters); Pierre-Fort Pierre, South Dakota (Bad River delta and Big Bend headwaters); the White River delta; Verdel and Niobrara, Nebraska (Niobrara River delta); and Springfield, South Dakota (Gavins Point headwaters.) These localized problems will continue to increase in severity if no remedial actions are taken. Additional information on each of these areas is presented in the following paragraphs.

Garrison headwater and backwater areas can extend upstream past the city of Williston, North Dakota. Corps-built levees protect Williston from the aggradation backwater effects. After construction of Garrison Dam, the Lewis and Clark and Buford-Trenton irrigation projects were operating in this backwater area. The Lewis and Clark project and a portion of the Buford-Trenton project were purchased by the Government for project lands. The remainder of the Buford-Trenton irrigation project continues to operate. Prior to 1979, there were numerous complaints and claims filed by landowners in this area alleging that high ground water levels resulted from the aggradation effects on the adjacent Missouri River near the Missouri-

Yellowstone confluence. Groundwater observation wells were monitored in this area in cooperation with the State of North Dakota since the construction of Garrison Dam. Studies indicated that acquisition of additional lands would be a less expensive alternative than any permanent structural solution to alleviate these problems. Acquisition of easements and relocation assistance under Public Law (P.L.) 91-646 began in fiscal year (FY) 1998. The project consists of the acquisition of permanent flowage and saturation easements within and surrounding the Buford-Trenton Irrigation District for land that has been affected by rising groundwater and the risk of flooding.

During the winter period, Fort Peck releases of 10,000 cfs or less at the time an ice cover initially forms are unlikely to result in damages on the reach of the Missouri River from Fort Peck to the Williston, North Dakota area. In high runoff years releases are generally decreased prior to the beginning of the winter period to prevent ice-jam flooding during the freeze-in period. After a stable ice cover is in place, releases may be gradually increased for the remainder of the winter period to meet critical winter hydropower demands. In drought years, winter release rates are generally low enough that a reduction during the freeze-in period is not necessary.

Continuing aggradation in the headwaters of Oahe has contributed to high water problems in the Bismarck, North Dakota area during the periods of high Garrison summer releases and during the winter ice-in periods. There is a considerable amount of new housing being developed along and near the Missouri River in the Bismarck-Mandan area. Releases from Garrison are reduced to 15,000 to 20,000 cfs during the winter ice-in period to prevent the stage at Bismarck from exceeding the critical ice-in stage of 13 feet. Flood stage at Bismarck is 14.5 feet. Once a stable ice cover is established in the Bismarck area, Garrison releases can be gradually increased.

Flooding in the Pierre-Fort Pierre area, especially at street intersections in the Stoeser Addition, has been a recurring problem since 1979. High Oahe releases, coupled with the formation of river ice downstream of the Pierre-Fort Pierre area, would cause water to back up into a storm sewer outlet flooding street intersections. P.L. 105-277, as amended by P.L. 106-224, authorized and funded the design and modification of infrastructure changes, acquisition of the most flood-prone properties, and flood-proofing other properties in the Fort Pierre and Pierre areas to prevent flood damages. Release restrictions were implemented in some previous years to prevent flooding. During periods of ice formation, a one-unit minimum may be imposed to prevent ice formation in the channel directly below Oahe Dam. In addition, peak hourly releases as well as daily energy generation will be constrained to prevent urban flooding in the Pierre and Fort Pierre areas if severe ice problems develop downstream of Oahe Dam. The MRBWMD office will coordinate any releases changes with the Western Area Power Administration (Western).

During the 1991 fall drawdown of the Fort Randall reservoir, it was observed that the White River delta, which extends across the reservoir, was having a damming effect that created two different reservoir elevations upstream and downstream of the delta. In the fall, when the reservoir is drawn down, there is a difference in pool elevations above and below the delta in the range of 8 to 11 feet. The Corps has published a revised elevation capacity table for Fort Randall

reflecting the effect of this phenomenon near elevation 1347 feet and below. Ongoing monitoring of this condition continues.

Sediment deposition in the vicinity of Springfield, South Dakota, has continued and may restrict access to Gavins Point reservoir from the Springfield boat ramp during periods of low reservoir elevation. Farther upstream, a large delta continues to develop near the mouth of the Niobrara River. The sediment deposition and related channel cross-section area changes from Niobrara downstream to Springfield increase the travel time of releases from Fort Randall to Gavins Point and has severely restricted the channel capacity through the 10-mile reach extending above the mouth of the Niobrara River. Continuing flows at the maximum Fort Randall powerplant capacity now result in some overbank flooding and water-logging in this reach. Long periods of high releases like 1997, 2011 or 2019 cause a notable, but temporary, increase in the channel capacity. With continued sedimentation the channel capacity again diminishes over time.

Downstream of Gavins Point, a general lowering trend (degradation) of the river bed and stages and the accumulation of sediment in marinas continue to be a concern for recreational boaters and marina operators. Sediment deposition resulting from high, short-duration flows, and extended periods of minimum service flow support have necessitated dredging of marinas below Gavins Point. During periods of extended drought, low release rates coupled with channel degradation in the Sioux City to Omaha reach and at Kansas City have adversely impacted powerplant and municipal water intake access downstream of Gavins Point.

D. Reservoir Water Quality

Water quality characteristics that are of greatest concern in the basin are chemical constituents, which affect human health, plant and animal life, and the various uses of water by man (e.g., irrigation, domestic and industrial uses); temperatures, which affect fisheries and the aquatic environment; biological organisms, which affect human health; and taste, odor and floating materials, which affect the water's potability and the aesthetic quality of the environment. Biologic quality and dissolved-oxygen quality have not been considered problems within the basin until recent years. As a result, there has not been a long-term watershed approach in obtaining basin-wide data, but it is known that problems exist below several of the major cities and below industrialized areas on some of the smaller tributary streams. High ambient air temperatures, solar radiation, water depth and thermal discharges from point sources can also affect thermal water quality conditions. Low releases could impact the operation of downstream powerplants.

Generally, System project release levels necessary to meet the downstream water supply purposes exceed the minimum release levels necessary to meet minimum downstream water quality requirements. The Missouri River minimum daily flow requirements for water quality that are given in Table 5 were initially established by the Federal Water Pollution Control Administration in 1969. They were reaffirmed by the EPA in 1974 after consideration of (1) the current status of P.L. 92-500 programs for managing both point and non-point waste sources discharging into the river, and (2) the satisfactory adherence to the dissolved-oxygen

concentration of 5.0 parts per million (ppm). The minimum daily flow requirements listed in Table 5 are to be used for System regulation purposes.

Table 5
Minimum Daily Flow Requirements below the System (in cfs)

Urban Area	December January February	March April	May	June July August September	October November
Sioux City	1,800	1,350	1,800	3,000	1,350
Omaha	4,500	3,375	4,500	7,500	3,375
Kansas City	5,400	4,050	5,400	9,000	4,050

The System and its regulation have significantly improved water quality in the Missouri River reaches between the reservoirs and downstream of the System, compared to the water quality in the Missouri River before the System was constructed. The water quality has improved, as seen through the Clean Water Act, because the river has become clearer and cooler and improved recreation and sport fishery. Conversely, the water quality has degraded, as seen through the ESA, because the natural turbid, warm river has become clearer and cooler which may affect native river fish. Downstream flow support from the System for the authorized purposes other than water quality more than meets the minimum flow requirements for Missouri River water quality. Water quality, therefore, has more than enough flow during all periods of the year in all of the Missouri River reaches. Water quality in the System reservoirs has been deteriorating for some time, essentially since the reservoirs were first filled. The dissolved-oxygen levels in the lower levels of the System reservoirs do not provide water quality conditions conducive to support some types of fish. The number of algae blooms has increased during the life of the System. Water quality has deteriorated in some arms of the large reservoirs for short periods so that the water in these locations is not potable, but these situations have been rare. In general, the water quality in the System reservoirs is considered good and is expected to remain so. Low flows in the reaches downstream from Garrison and Gavins Point dams directly affect the ability of thermal powerplants in these two reaches to meet National Pollutant Discharge Elimination System permit standards for discharging cooling water back into the Missouri River. Low reservoir levels and river stages may increase the sediment content in water supplies and result in depleted dissolved oxygen conditions in powerplant releases and tailwater areas.

IV. RECURRING OPERATIONAL CONSIDERATIONS

A. Flood Control

Flood control is the only authorized project purpose that requires the availability of empty storage space rather than impounded water. Actual flood events are generally unpredictable; therefore, detailed routing of specific major flood flows is accomplished when floods occur. There is a recurring pattern of high-risk flood periods during each year: a season when snowmelt, ice jams, and protracted heavy rains will almost surely occur with or without generating

consequent floods; and a season when these situations are most unlikely and the flood threat is correspondingly low. The high-risk flood season begins about March 1 and extends through the summer. As a consequence, regulation of the System throughout the fall and winter months is predicated on starting the runoff season, which begins on or about March 1, with all flood control storage available to capture runoff. The goal is to have the System storage at or below the base of the Annual Flood Control and Multiple Use Zone before the start of the next runoff season. Exceptions to this will occur due to the availability of replacement flood control storage in major upstream tributary reservoirs, which is outlined in Section 7-04.4 of the Master Manual. This type of storage, available in the USBR's Clark Canyon, Canyon Ferry and Tiber Reservoirs, can effectively reduce the requirements for annual flood control storage in the System. The available storage for control of flood inflows in the combined System and tributary reservoirs has been scheduled in the past as discussed above after coordinating with the USBR in Billings, Montana; however, it has not been utilized in recent years.

Due to release limitations imposed by the formation of a downstream ice cover, a major portion of the required flood control space in the System must be evacuated prior to the winter season. Gavins Point winter releases exceeding 25,000 cfs are not normally scheduled. While higher winter Gavins Point releases have been made, the release decision must consider downstream ice conditions and/or the amount of stored flood waters needed to be evacuated. Since the impacts of ice-jam flooding can be more severe when higher releases are made during the winter months, careful consideration and additional vigilance is required.

In general, individual System projects will also be scheduled to be near or below their respective base of annual flood control by March 1. Some departure is possible due to the availability of upstream tributary flood control storage space, and/or recognition of the relative ease by which the water in storage may be transferred downstream to other projects in the System even during the flood season.

During all but excessively below-average runoff years, water stored in the reservoirs will increase during the March-July period. The base of Exclusive Flood Control Zone defines the maximum level of storage that will be accumulated for purposes other than flood control. Water stored in the projects' Annual Flood Control and Multiple Use zones will normally be released through the powerplant of each of the individual projects except when evacuation of this zone prior to the winter season necessitates higher flow rates requiring flood control outlet tunnel or spillway releases. When water enters the Exclusive Flood Control Zone in a particular reservoir, the control of subsequent flood inflows becomes the paramount factor. During such periods, releases may substantially exceed the powerplant release capacity with the evacuation rate of any project dependent upon existing flood conditions, the potential for further inflows, and conditions of other reservoirs in the System. Maximum release rates at such times are based on the flood control criteria outlined in the Master Manual and the flood control status of the System. Detailed information regarding the adjustment of service levels for flood control evacuation and downstream flood control constraints can be found in Chapter 7 of the Master Manual.

B. Water Requirements below Gavins Point

Gavins Point releases are regulated to provide service to all multiple-use purposes, while at the same time recognizing the important flood control function of the System. In years of excess water supply, Gavins Point Dam releases in excess of full service requirements may be necessary to evacuate stored flood water. The magnitude of these evacuation releases during the open-water season may be reduced somewhat by scheduling winter releases at a higher rate than would be the case with average water supply. This may increase the service provided to the hydropower and navigation purposes by extending the navigation season length up to 10 days and increasing the amount of winter hydropower generation. Also, flood storage evacuation releases slightly above full service requirements during the open-water season usually have a beneficial effect on navigation and hydropower generation. With an average or less-than-average water supply, navigation and hydropower releases during the open-water season are made taking into account the existing System water in storage and less-than-full service level releases may be provided when water in storage indicates water conservation measures are in effect. If navigation season lengths need to be reduced to less than 8 months, per the criteria outlined in the Master Manual, winter releases from Gavins Point may be reduced to the minimum necessary for water intake or water quality control requirements. The minimum System releases considered applicable at this time are 9,000 cfs during the non-summer open-water season (March-April and September-November), 18,000 cfs during the summer open-water season (May-August) and 12,000 cfs during the winter period (December-February).

1. Navigation Season Requirements. The 735-mile Missouri River navigation channel extends from the confluence of the Big Sioux and Missouri Rivers near Sioux City, Iowa to the river's mouth near St. Louis, Missouri. Flow support for navigation has been provided since June 1967, when the System closed. While flow support for navigation is for a defined period of time each year (e.g., a full-length season is 8 months), navigators can be on the Missouri River all year, if flow and ice conditions permit. Downstream flow support is provided to meet many of the Congressionally authorized purposes, which includes navigation. The Bank Stabilization and Navigation Project (BSNP) was constructed and is maintained to create a self-scouring channel that provides a 9-foot deep and 300-foot wide navigation channel with full service flows. Construction of the BSNP was declared essentially complete in September 1981; although maintenance and corrective work will be required as the Missouri River continues to form its channel in response to changing flow conditions. Navigation flow support is provided to maintain an 8- to 9-foot depth in the navigation channel for minimum and full service flow support, respectively, depending on the amount of water stored in the System on March 15 and July 1. The navigation season is extended for 10 days in higher runoff years to facilitate evacuation of stored flood waters prior to the next flood season.

a. Navigation Service Level and Season Length. As described in the Master Manual, flow support for navigation and other downstream purposes is defined based on service level. System storage on March 15, as shown in **Table 6**, is used to determine the navigation service level for the first half of the navigation season. System storage on July 1, as shown in **Table 6**, is used to determine the navigation season level for the second half of the navigation season as well as the season length. Navigation service level is defined as "full", "minimum", or "intermediate". Full service navigation flow support is provided in near-normal runoff years

to provide for evacuation of flood control storage prior to the next flood season, while serving navigation to the full capability of the authorized 9-foot downstream channel (8.5-foot draft). Minimum service navigation flow is usually provided in drought times to provide a minimum level of navigation service (7.5 feet of draft) while conserving water in the System in case of an extended drought. Intermediate service navigation flow support is provided when System storage is between 54.5 and 49.0 MAF on March 15 or 57.0 and 50.5 MAF on July 1. A full service level of 35,000 cfs results in target discharges of 31,000 cfs at Sioux City and Omaha, 37,000 cfs at Nebraska City and 41,000 cfs at Kansas City. Similarly, a minimum service level of 29,000 cfs results in target values of 6,000 cfs less than the full service levels at the four System control points identified above.

Table 6
Relation of Navigation Service Level to System Storage

Date	Service Level (cfs)	Water in System Storage (MAF)
March 15	35,000 cfs (full service)	54.5 or more
March 15	29,000 cfs (minimum service)	49.0 to 31.0
March 15	(no service)	31.0 or less
July 1	35,000 cfs (full service)	57.0 or more
July 1	29,000 cfs (minimum service)	50.5 or less

Day-by-day regulation of the System to support navigation requires forecasts of inflow to various reaches of the Missouri River below the System. From these forecasts and current flow targets, the control point (either Sioux City, Omaha, Nebraska City or Kansas City) is determined each day. Anticipated commercial barge traffic or the absence of commercial barge traffic at the control points will also have a bearing on the control point selection. For this reason, the MRBWMD office will continuously monitor traffic movement on the Missouri River. After selection of the control point, releases from the System are adjusted so that, in combination with the anticipated inflows between the System and the control point, they will meet the target flow at the control point.

The System water-in-storage checks to determine the navigation service level occur on constant key dates (March 15 and July 1) of each year. The volumes selected have been derived from long-range model simulations that allow the System to function to meet authorized purposes during significant multi-year drought periods. The specific technical criteria for navigation service level are shown in **Table 6**. Straight-line interpolation defines intermediate service levels between full and minimum service. These navigation service level determinations are for water conservation and normal System regulation. During years when flood evacuation is anticipated and/or required, the service level will be calculated monthly, and mid-monthly if needed, based on Plate VI-1 in the Master Manual, to facilitate a smooth transition in System release rather than a stepped approach at the March 15 and July 1 dates.

As shown in **Table 6**, the Master Manual calls for suspension of navigation flow support if System water in storage is at or below 31.0 MAF on March 15 of any year. It should be noted that the occurrence of System storage at or below 31.0 MAF would most likely coincide with a

national drought emergency. If any of the reservoir regulation studies performed for the development of the AOP indicate that System storage will be at or below 31.0 MAF by the upcoming March 15, the Corps will notify the Secretary of the Army. Approval from the Secretary of the Army will be required prior to suspension of Missouri River navigation for the second of two consecutive years. The Corps will ensure that basin stakeholders are promptly informed of the notification to the Secretary of the Army and of the Secretary's decision regarding suspension of navigation flow support.

If System water in storage is above 31.0 MAF on March 15, navigation flow support will be provided. The water-in-storage check for navigation season length is taken on July 1 of each year. As shown in **Table 7**, if System water in storage is at or above 51.5 MAF on July 1, flow support for a full 8-month navigation season would be provided, unless the season is extended to evacuate System flood control storage. However, if System water in storage falls below 51.5 MAF on any July 1, flow support for a shortened navigation season would be provided to conserve water stored in the System to extend availability of water in storage in the case of an extended drought. The specific technical criteria for navigation season length are shown in **Table 7**. Straight-line interpolation between 51.5 and 46.8 MAF of water in storage on July 1 provides the ending date for flow support for a navigation season length between 8 and 7 months. If System water in storage on July 1 is between 46.8 and 41.0 MAF, flow support for a 7-month navigation season is provided. A straight-line interpolation is again used between 41.0 and 36.5 MAF, providing flow support for a navigation season length between 7 and 6 months. For System water in storage on July 1 below 36.5 MAF, flow support for a 6-month navigation season is provided.

Table 7
Relation of System Storage to Navigation Season Length

Date	System Storage (MAF)	Final Day of Navigation Support at Mouth of the Missouri River
March 15	31.0 or less	No season
July 1	51.5 or more	November 30 - 8-month season
July 1	46.8 through 41.0	October 31 - 7-month season
July 1	36.5 or less	September 30 - 6-month season

The System releases required to meet the minimum and full service targets vary by month in response to downstream tributary flows. In general, more water was needed downstream to support navigation during years with below-average upper basin runoff than during years with above-average upper basin runoff. Regulation studies performed since 1999, therefore, use two levels of System release requirements; one for median, upper quartile, and upper decile runoff scenarios and another for lower quartile and lower decile scenarios. In general, early in the navigation season the flow target is normally at Sioux City with adequate downstream tributary flows to meet flow targets. Normally, as the runoff season progresses, downstream tributary flows recede or cease during the summer, and the flow target moves from Sioux City to Nebraska City and eventually to Kansas City. This requires higher flow support (i.e., higher Gavins Point releases) as the season progresses through the summer. Normally, the target moves

upstream during the fall, when higher downstream tributary flows return. This seasonal tributary flow pattern is reflected in the Gavins Point Dam release data presented in **Table 8**. These releases are the average monthly values during the period studied for the various runoff conditions and do not reflect the maximums and minimums required during that month to meet flow targets. Actual regulation requires daily adjustments to fully serve the Congressionally authorized project purpose of navigation. Flow targets may not be met in upstream reaches without commercial navigation; therefore, the actual target location may be affected by the absence or presence of commercial navigation in a reach.

Table 8
Gavins Point Releases Needed to Meet Downstream Targets (in kcfs)

Median, Upper Quartile, Upper Decile Runoff								
Service Level	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Full	26.7	28.0	27.9	31.6	33.2	32.6	32.0	31.1
Minimum	20.7	22.0	21.9	25.6	27.2	26.6	26.0	25.1
Lower Quartile, Lower Decile Runoff								
Service Level	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Full	29.8	31.3	31.2	34.3	34.0	33.5	33.1	31.2
Minimum	23.8	25.3	25.2	28.3	28.0	27.5	27.1	25.2

b. <u>Release Patterns during T&E Nesting Season</u>. During the 2003 T&E nesting season, a new procedure, called "steady release – flow to target" (SR-FTT), was used to set the Gavins Point Dam release. This procedure combined features of the original "flow-to-target" method with the "steady release" plan, which are described in the Master Manual. The SR-FTT procedure called for an initial steady release high enough to inundate low-lying habitat that would likely be subject to inundation later in the season. Since 2003, the SR-FTT procedure has been identified in the AOPs as the regulation scenario to be followed because it meets the project purposes while minimizing the loss of nesting T&E species. As downstream tributary flows decline through the summer, System releases are increased as needed, within the limits of the Incidental Take Statement as outlined in the 2018 Biological Opinion, to meet other downstream purposes, such as navigation.

Releases from Gavins Point may be increased every third day to encourage the T&E birds to build their nests on higher habitat so that the nests would not be inundated later when higher releases are required to meet the regulation objectives of the System. This pattern of increasing releases every third day is referred to as "cycling". Cycling is generally not used during years when System storage is high but has been used during extended drought, when water conservation is of primary importance. Cycling is suspended when T&E chicks hatch to reduce the risk of stranding chicks on low-lying sandbars. Unfledged chicks can be lost if stranded on low-lying sandbars that are subsequently totally inundated. Cycling of Gavins Point releases when releases are reduced for downstream flood control during the protected bird species nesting season has also been used to keep birds nesting at sufficiently high elevations to maintain room for release increases when downstream flooding has subsided. The daily variation in releases is normally limited to 6,000 to 8,000 cfs to minimize adverse effects on downstream river users and fish.

2. Non-navigation Season Requirements. When releases are not being made for downstream flow support during navigation season, other factors, including water quality control and water supply, are used to establish the System release rates.

a. Water Quality Control. The regulation of the System under the Master Manual has significantly improved water quality in the river reach downstream of the System, as defined by State water quality standards, compared to the water quality in the Missouri River before the System was constructed. System project release levels necessary to meet downstream water supply purposes generally exceed the minimum release levels necessary to meet minimum downstream water quality requirements. The Missouri River minimum daily flow requirements for water quality control that are given in **Table 9** were initially established by the Federal Water Pollution Control Administration in 1969. They were reaffirmed by the Environmental Protection Agency in 1974 after consideration of (1) the current status of PL 92-500 programs for managing both point and non-point waste sources discharging into the river, and (2) the satisfactory adherence to the dissolved-oxygen concentration of 5.0 parts per million (ppm).

Table 9
Minimum Daily Flow Water Quality Requirements (in cfs)

Urban Area	December January February	March April	May	June July August September	October November
Sioux City	1,800	1,350	1,800	3,000	1,350
Omaha	4,500	3,375	4,500	7,500	3,375
Kansas City	5,400	4,050	5,400	9,000	4,050

Low flows downstream from Gavins Point Dam may affect the ability of thermal powerplants to meet National Pollutant Discharge Elimination System (NPDES) permit standards for discharging cooling water back into the Missouri River and may increase the sediment content in some water supply systems.

b. Water Supply. Numerous water intakes are located along the Missouri River below the System and in reaches between the projects. These intakes are primarily for the purposes of municipal water supplies, nuclear and thermal powerplant cooling, and irrigation supplies withdrawn directly from the Missouri River. Historically, water access problems have been associated with several of these intakes; however, the problems have been primarily a matter of sandbars or sediment deposition at the intake restricting access to the river rather than insufficient water supply. Other water supply problems can occur during the winter months due to ice jamming on the river. Floating or frazil ice can block the water intake facilities directly, which can reduce the intake flow to unacceptable rates.

The minimum daily flow requirements established for water supply are designed to prevent operational problems at municipal and thermal powerplant intakes at numerous locations along the Missouri River below the System. The lower Missouri River is significant with regard to water supply. Nearly 90 percent of the population served, and 75 percent of the thermal power

generating capacity using the Missouri River for once-through cooling, are located below the System. Problems that have been experienced within the System are related primarily to intake elevations or river access rather than inadequate water supply. Evaluations are conducted on an on-going basis, specifically during years when non-navigation and lower-than-average winter releases are made, between the Corps and affected water users to determine the minimum stage and flow requirements at each intake location for satisfactory hydraulic operation.

Lower flow targets of 9,000 cfs are included in the non-summer, open-water-season months, and these releases may not be adequate to meet water supply needs below the System on the Missouri River without modifications to some intakes, particularly those in the degradation reaches at Sioux City and Kansas City. The Corps will continue to obtain the necessary data and make adjustments to the System to assure that this occurs; however, the intake access associated with obtaining Missouri River water is the responsibility of the entity choosing to use this source of water for its supply. Intake access problems are the responsibility of the intake owner, and the Corps will not guarantee access; rather, only that, to the extent practicable, the supply of water in the Missouri River is adequate to meet this project purpose.

3. Integration of Downstream Requirements. When the water in storage in the System is at normal or higher levels, releases for the navigation and power production purposes and to evacuate flood control storage during the navigation season and winter period will normally be at levels that are deemed sufficient to meet downstream water supply needs. During extended droughts, Gavins Point Dam releases may be reduced as the service level is reduced, as outlined in the Master Manual. During any non-navigation period, releases will be made to ensure adequate flows to serve water supply in the river reaches downstream of the System and between the Systems dams, to the extent reasonably possible. The minimum open-water season System release is 9,000 cfs. Some intakes require more than 9,000 cfs during the open-water season for effective operation. The intake owners bear the responsibility to modify their intakes to ensure that they can remain operational at lower System release rates. During drought years when System storage is low enough to reduce or eliminate the navigation season, a Gavins Point Dam release of 18,000 cfs has been established as meeting the summer water supply requirement. The intake owners bear the responsibility to modify their intakes if a summer Gavins Point Dam release rate of 18,000 cfs will not be adequate to meet their needs.

The winter System release rate is determined based on a September 1 System water-in-storage check and prorated from 17,000 cfs (at 58.0 MAF or more) to 12,000 cfs (at 55.0 MAF or less). This release rate in combination with average downstream tributary flows is normally sufficient to meet downstream water supply intake requirements, but may be adjusted based on tributary flows and the potential for ice formation. A winter Gavins Point Dam minimum release rate of 12,000 cfs has been established as the guide in meeting downstream water supply requirements during this period. Intakes typically have higher requirements during the winter period because of the effects of river ice in reducing the capacity of their intakes. If Gavins Point Dam release rates are reduced below 12,000 cfs for water conservation, continued surveillance of these intakes will be required, and, if appropriate, additional releases may be required to assure adequate water levels for uninterrupted intake operation. During the critical and more difficult winter period, release rates may be adjusted according to river icing conditions to assure that the water supply service is provided downstream.

C. Water Requirements above Gavins Point.

The regulation of the System under the Master Manual has significantly improved water quality and water supply in the region compared to conditions prior to the construction of the System. However, low reservoir levels and reduced releases during periods of extended drought contribute to both intake access and water quality problems in the upper basin, including problems at several Tribal intakes.

1. Water Quality Control. Water quality characteristics that are of greatest concern in the basin are chemical constituents, which affect human health, plant and animal life, and the various uses of water by man (e.g., irrigation, domestic and industrial uses); temperatures, which affect fisheries and the aquatic environment; biological organisms, which affect human health; and taste, odor and floating materials, which affect the water's potability and the aesthetic quality of the environment. Biologic quality and dissolved-oxygen quality have not been considered problems within the basin until recent years. As a result, there has not been a long-term watershed approach in obtaining basin-wide data, but it is known that problems exist below several of the major cities and below industrialized areas on some of the smaller tributary streams. High ambient air temperatures, solar radiation, water depth and thermal discharges from point sources can also affect thermal water quality conditions. Low releases could impact the operation of downstream powerplants.

2. Water Supply. The minimum releases established for water supply are designed to prevent operational problems at municipal and thermal powerplant intakes at numerous locations along the Missouri River. Similar to problems that have been experienced within the System at other locations, this is generally a matter of intake elevations or river access rather than inadequate water supply. Releases will be made to ensure adequate flows to serve water supply in the river reaches between the System dams, to the extent reasonably possible. Intake access problems are the responsibility of the intake owner, and the Corps will not guarantee access; rather, only that, to the extent practicable, the supply of water in the Missouri River is adequate to meet this project purpose.

Historic regulating experience indicates that a minimum daily average release of 3,000 cfs from Fort Peck Dam is satisfactory for municipal water supply. A year-round instantaneous minimum release of 3,000 cfs was established at Fort Peck in 1992 for the trout fishery located in the dredge cuts immediately below Fort Peck Dam. The irrigation demands below Fort Peck Dam during the irrigation season currently call for a flow of 6,000 cfs as a minimum; however, the formation of sandbars has at times restricted flows to some intakes in this reach. The Fort Peck Dam minimum release rate is, therefore, equal to or greater than the minimum water supply release requirement for this reach.

At Garrison Dam, a minimum average daily release of at least 9,000 cfs during both the open-water and ice-cover seasons is desirable to provide sufficient river depths for satisfactory operation of municipal, irrigation and powerplant water intakes in North Dakota. In this reach of the river, fluctuations in release levels require, at times, the resetting of irrigation pumping facilities to achieve access to available water or to prevent inundation of pumps.

No restriction on minimum releases from Oahe and Big Bend is necessary for adequate service to water intakes because the headwaters of downstream reservoirs may extend to near the upstream dam sites. Minimum flows from Oahe of at least 3,000 cfs may be scheduled as needed during the daylight hours during the recreation season.

Presently, there are no withdrawals from the Missouri River in the reach extending from below Fort Randall to the headwaters of the Gavins Point reservoir for municipal and industrial purposes. The city of Springfield, South Dakota withdraws water from the Gavins Point reservoir headwaters region. However, the intake is affected primarily by Gavins Point reservoir levels rather than the magnitude of releases from Fort Randall.

D. Power Production.

Since completion of the power installations at the System projects, most System project releases have been made through the respective powerplants. When release requirements were exceptionally high due to flood control storage evacuation, or one or more of the hydropower generation turbines are off line, spillway releases are necessary at Gavins Point Dam. Some spillway releases have also been required at Fort Peck, Garrison and Fort Randall Dams for these reasons; however, in most years releases from all projects are made through the powerplants at all times. The six System dams support 36 hydropower units with a combined plant capacity of 2,523 megawatts (MW) of potential power generation. These units provide an average of 9.3 million MWh of energy per year, which is marketed by Western. Power generation at the six System dams generally must follow the seasonal pattern of water movement through the System; however, adjustments are made, when possible, to provide maximum power production during the summer and winter when demand and value of this authorized purpose is highest. Hydropower is the only Congressionally authorized purpose of the System that actually returns money to the U.S. Department of the Treasury.

The aggregate installed capacity of all powerplants in the Missouri River basin exceeds 20,000 MW, with an annual generation of over 90 million MWh. The investor-owned systems have about 60 percent of the basin's generating capacity. The publicly-owned systems consist of about 40 percent federal hydroelectric capacity and 60 percent thermal capacity owned by non-federal public bodies. Hydropower installations in the basin total about 3,000 MW, of which about 82 percent is federal, 14 percent is investor owned, and 4 percent is publicly owned. Western, of the U.S. Department of Energy, markets power generated at the System dams within the Southwest Power Pool (SPP). Western joined the SPP market in October 2015. Western had previously marketed energy in the Mid-continent Area Power Pool region.

The federal power system in the upper Missouri River basin includes the six Corps System powerplants as well as the Canyon Ferry and Yellowtail powerplants constructed by the USBR. Until October 1, 1977, energy from all Missouri River basin federal powerplants was marketed by the USBR. At that time, the power marketing responsibility shifted to Western. The federal hydroelectric powerplants are connected with the extensive federal transmission system within Western's Eastern Division, Pick-Sloan Missouri Basin Program, power-marketing area, which includes Montana east of the Continental Divide, North Dakota, South Dakota, eastern Nebraska, western Minnesota, and western Iowa. The transmission network is interconnected with numerous Rural Electric Association-financed cooperatives, municipal

power systems, and investor-owned utilities. The Eastern Division transmission network is interconnected with Southwestern at Maryville, Missouri, and with the Western Division through a 100 MW direct current tie at Stegall, Nebraska, owned by the Tri-States Cooperative. In addition, by a split-bus operation, a variable number of units can be operated on the Western System at the Fort Peck and Yellowtail (USBR reservoir project) powerplants. **Table 10** presents hydropower-related information for the System dams.

Table 10
System Project Hydropower Data

Dam	Generator Capacity (MW)	Energy (million MWh)	Average Annual Energy Plant Factor (%)	Units	Average Gross Head (feet)	Average Flow (kcfs)	Normal Powerhouse[1] Capacity (kcfs)	Average Annual Flow Plant Factor (%)	Type
Fort Peck	185	1.0	63	5	194	9.2	16	58	Semi-Peaking
Garrison	583	2.2	43	5	161	21.6	41	53	Semi-Peaking
Oahe	786	2.6	38	7	174	23.2	54	43	Peaking
Big Bend	517	1.0	22	8	70	23.7	103	22	Peaking
Fort Randall	320	1.7	61	8	118	25.1	44.5	56	Semi-Peaking
Gavins Point	132	0.7	62	3	48	27.6	36	77	Baseload
Total	**2,523**	**9.3**		**36**					

[1] Normal powerhouse capacity is based on average reservoir elevation.
Note: Flow plant factors are calculated based on average flows versus powerhouse flow capacities. These differ from energy-based plant factors to the extent that actual plant head is less than maximum gross head.
Source: Corps, 1967-2015 actual data.

E. Irrigation.

Releases from the reservoirs are used by numerous private irrigators and by federally-financed projects. Private irrigation directly from the reservoirs is ongoing and continues to develop. While the minimum releases established for water quality or for satisfactory operation of Missouri River water supply intakes are usually ample to meet the needs of irrigators, low reservoir levels and low river stages, with their associated exposure of sandbars and drying up of secondary channels, make access to the available supply difficult or inconvenient to obtain. The System will continue to be regulated for this Congressionally authorized project purpose and the Corps will adjust project releases to meet irrigation needs, to the extent reasonably possible. Access is the major problem for all types of intakes along the Missouri River and on the System reservoirs. The intake owners bear the responsibility to modify their intakes if adequate water supplied for irrigation is not accessible.

F. Recreation.

The six reservoirs of the System and the Missouri River reaches between and downstream of these reservoirs provide recreation opportunities. Recreational activity is a source of income

for businesses catering to boating, hunting, fishing, camping and other recreational pursuits. Service-related establishments located near the Missouri River also benefit from those recreating on the System reservoirs. Water-based recreation includes boating, fishing and swimming. Sport fishing is a primary component of recreation along the entire Missouri River. The wetlands along the river corridor provide waterfowl habitat, and waterfowl hunting is popular.

Water levels are a key factor in recreational use of the reservoirs and river reaches. The lower three reservoirs, Big Bend, Fort Randall and Gavins Point, are generally regulated in a consistent manner regardless of inflows and total System storage. Pool levels at the upper three reservoirs, however, vary widely in response to drought conditions. Although recreation may be affected by high reservoir levels and releases, periods of extended drought that result in significant lowering of reservoir levels and releases have a greater impact. At low reservoir levels, some boat ramps and recreational areas may not provide access to the reservoirs. Low releases may impact boat access and maneuverability between and below System dams. During the two major droughts since the System first filled, many boat ramps were extended or relocated to maintain access. Shortening of the navigation season during droughts also has the effect of shortening the recreation season below the System due to the greatly reduced flows, and the shortening also results in an earlier drawdown for Fort Randall, impacting recreation access on the Fort Randall reservoir (Lake Francis Case).

G. Fish and Wildlife.

Since the System filled in 1967, the System reservoirs have been regulated to enhance the fish population associated with the reservoirs. A diverse community of coldwater and warmwater fish inhabit the six reservoirs of the System. The upper three larger reservoirs have been stocked with coldwater game and forage species to take advantage of the cold water retained through the summer and fall in the deeper waters of the reservoirs when the storage in these reservoir has not been depleted by drought. The greater-than-expected improvement in upstream recreation is directly related to the enhancement of the fishing and wildlife activities associated with the System reservoirs. Large areas are preserved for the diverse basin wildlife on System project lands. The success of the fish in the System reservoirs and on the Missouri River below each System dam depends on habitat conditions. Water levels, inflow and outflow are important factors in the reservoirs. Native fish in the river reaches are naturally adapted to warm, muddy high spring and early summer flows, and also to the lower late summer and fall flow characteristics of the historic Missouri River. The cold, clearer tailwaters of the upper three large System reservoirs are more conducive to trout and salmon, but not paddlefish, pallid sturgeon and other native river fish. In addition, the System regulation must consider protection for the three ESA-listed species: the threatened interior least tern, the endangered piping plover, and the endangered pallid sturgeon.

1. Fish. Fish production and development in the System is related to water levels and releases during the spawning period and the availability of appropriate habitat. The federal and state fish and wildlife agencies recognize that water supply is not always adequate, making it impossible to regulate each reservoir each year for optimum fish management. Therefore, one or more System reservoirs may be selected each year to emphasize improvement of fish management to the extent that inflows and requirements for other purposes allow.

a. <u>Regulation during Fish Spawn</u>. The ability to provide steady-to-rising levels in the upper three System reservoirs in low-runoff years is dependent on the volume, timing and distribution of runoff. The current method of managing reservoir levels during the spawn consists of rotating emphasis between Garrison one year and both Fort Peck and Oahe the following year. During Garrison's year, a steady-to-rising pool is accomplished by adjusting the releases from Fort Peck and Garrison. The following year, a rising pool at Oahe is accomplished through adjustments in Garrison's releases; however, these adjustments may be restricted when the T&E species begin nesting in May. At Fort Peck, a steady-to-rising pool is accomplished by setting releases at a level that maintains a steady-to-rising pool, but no less than the minimum required to meet the needs of the coldwater fishery immediately downstream of the dam and irrigation needs below the project. The upper three reservoirs are managed to benefit the reservoir fisheries, to the extent reasonably possible, while continuing to serve the other Congressionally authorized project purposes. The plan may also be adjusted to be opportunistic in regard to runoff potential and will continue to evolve as additional information becomes available.

b. <u>Conservation of Coldwater Habitat</u>. The Fort Peck, Garrison and Oahe reservoirs maintain "two-story" fisheries that are comprised of warmwater and coldwater species. The ability of these reservoirs to maintain "two-story" fisheries is due to their thermal stratification in the summer that allows coldwater habitat to be maintained in the deeper, colder region of the reservoir (i.e., hypolimnion). Warmwater fish species inhabit the warmer, shallower areas of the reservoirs (i.e., epilimnion), while coldwater species inhabit the hypolimnion. Certain coldwater fish species are used extensively as forage by both coldwater and warmwater predator fish in the reservoirs. Maintaining healthy populations of these coldwater forage fish is important to maintaining both the coldwater and warmwater recreational fisheries in the three reservoirs.

Two water quality parameters, temperature and dissolved oxygen, are of prime importance regarding the maintenance of coldwater fishery habitat in the hypolimnion of these reservoirs. During the summer, as the reservoir water temperature increases, the amount of coldwater habitat available decreases as the hypolimnetic volume decreases. Also, during summer thermal stratification, the reservoirs are experiencing ongoing degradation of dissolved oxygen in the hypolimnion as accumulated organic matter at the reservoir bottom decomposes. The situation becomes most critical later in the summer when the reduced volume of colder water and the increasing volume of low dissolved oxygen at the reservoir bottom combine to limit the occurrence of suitable coldwater habitat. The situation is exacerbated by drought conditions that lower pool levels and dam releases that draw hypolimnetic water from the reservoir bottom. Of the upper three reservoirs, the greatest impact on the coldwater habitat is at Garrison, where the intake structure draws releases off the bottom of the reservoir. In 2005, plywood was bolted to the lower 50 feet of the trash racks on two of the penstocks to allow water to be drawn from a higher, therefore, warmer region of the reservoir. In 2007, plywood was installed on one additional trash rack. In addition, the manner in which the other hydropower units were operated was adjusted to operate them at full or near-full capacity when in use, which also has the effect of drawing water off the upper portion of the reservoir. In combination, these two efforts saved up to 800,000 acre-feet of coldwater habitat in the reservoir each year for the benefit of the

coldwater fishery. Should another drought occur and the Garrison reservoir coldwater habitat become an issue, these actions, installing plywood on trash racks and operating hydropower units at full or near-full capacity, should be considered.

2. Wildlife. The USFWS manages the Charles M. Russell National Wildlife Refuge (CMR NWR). The CMR NWR encompasses the entire Fort Peck project and covers approximately 1.1 million acres. The wetlands along the river corridor provide waterfowl habitat, and waterfowl hunting is popular. Hunting for small and large game such as pheasant, grouse, rabbit and deer occurs on land along the System reservoirs and the Missouri River reaches.

3. Threatened and Endangered Species. The Endangered Species Act of 1973, as amended, provides for the protection of federally listed T&E species. The ESA requires federal agencies to ensure that their actions do not jeopardize the continued existence of a threatened or endangered species.

a. ESA Consultation History. In 1985 the interior least tern and the piping plover were federally listed as endangered and threatened species, respectively. These small shore birds nest on barren, low-lying sandbars and islands downstream from Fort Peck, Garrison, Fort Randall and Gavins Point from early May through mid-August. When available, the birds also use beaches and islands on the reservoirs for nesting. The pallid sturgeon was federally listed as an endangered species in October 1990. The Corps and the USFWS first completed formal Section 7 ESA consultation for terns and plovers on the regulation of the System in 1990.

As part of formal consultation, the USFWS's 2000 Biological Opinion on the Operation of the Missouri River Main Stem Reservoir System, Bank Stabilization and Navigation Project, and the Kansas River Reservoir System (2000 BiOp) concluded that the Corps' proposed action jeopardized the continued existence of the listed pallid sturgeon, piping plover, and interior least tern. The 2000 BiOp also recommended a Reasonable and Prudent Alternative (RPA) to avoid jeopardy. The Corps reinitiated formal consultation with the USFWS, providing a Biological Assessment (BA) with new proposed actions. After additional consultation in 2003, the USFWS amended its 2000 BiOp with the determination that the new proposed actions would avoid jeopardizing the continued existence of the two listed birds, but would jeopardize the continued existence of the endangered pallid sturgeon. The 2003 Amended BiOp included an RPA that included a provision for the Corps to develop a plan to implement a bimodal "spring pulse" from Gavins Point. In March 2006, the Master Manual was revised to include technical criteria for a bimodal spring pulse.

The Corps again conducted consultation with USFWS as part of the MRRMP-EIS resulting in a new BiOp being issued in April 2018. In November 2018, a Record of Decision (ROD) for the MRRMP-EIS was signed. The MRRMP-EIS established an overarching adaptive management process for implementation of actions required to avoid jeopardizing the listed species in the Missouri River basin as a result of Corps projects. After thorough analysis and input by the public, the ROD required the modification of the Master Manual to remove technical criteria for the bimodal spring pulse and reservoir unbalancing.

b. Regulation during Nesting Season. Prior to their federal listings, tern and plover nests were periodically inundated as a result of project releases for flood control, navigation, and hydroelectric power generation. Since the time they were listed, the Corps has participated in habitat and population studies relative to the interior least tern and the piping plover in the Missouri River reach from Fort Peck, Montana to Ponca State Park, Nebraska. In the past, the Corps has provided additional habitat by removing vegetation from higher elevation islands and creating higher elevation habitat at historic nesting sites. Nesting use is monitored at these sites. The Corps is striving to avoid adverse impacts on these species and will continue to adjust System regulation to benefit federally listed T&E species while continuing to serve all authorized project purposes. Ten streamgages were automated with satellite data collection platforms between 1986 and 1988 in the Missouri River downstream from Garrison, Fort Randall and Gavins Point to provide information to correlate nesting habitat with reservoir releases. The river reaches have been modeled using dynamic modeling so that stages can be estimated for various release patterns prior to making the releases; however, the models cannot accurately predict stage increases and nest flooding due to rainfall runoff events.

Releases from the mainstem projects are closely monitored during the nesting season. A uniform peaking release pattern has been established during the summer months at Garrison and Fort Randall for T&E nesting along the river reaches below these projects. In the past, a peaking pattern was also established at Fort Peck; however, recent nesting patterns below that project have made it unnecessary. If nesting patterns change in the future, the peaking pattern at Fort Peck may be re-established. Additionally, when possible releases from Gavins Point are adjusted when the birds arrive to provide the System flexibility to meet navigation target flows later in the T&E nesting season when downstream tributary flows begin their normal decline in July and August. Additional information on these adjustments, including the steady release – flow-to-target (SR-FTT) and cycling is presented in Section B.1.b on page 28 and in Section 7-10.3 in the Master Manual.

4. Environment. Development of the System has transformed a major portion of the Missouri River valley extending from eastern Montana through the Dakotas from an area typical of alluvial streams into a chain of long, relatively deep reservoirs. This development, in an area where such a quantity of surface water did not exist naturally and that is characterized as having a relatively dry climate, has had a great effect on the environment of the area. The purchase and subsequent management of lands associated with the individual System projects has changed use patterns of lands adjacent to the System projects from the use experienced prior to projects. Regulation of the reservoirs also has affected the regime of the Missouri River through those reaches below the System and in those reaches between the System reservoirs where the river is still more or less in its natural state. The full impact of each of the reservoirs and its regulation on the environment is constantly changing as they adapt to new conditions. Current efforts are focused on increased stewardship of the Missouri River and surrounding affected lands by maintaining them in as natural a condition as possible through enhancing and supporting native plants and species. The two basic goals of the Corps stewardship are to manage lands and waters to ensure their availability for future generations and to help maintain healthy ecosystems and biodiversity. Balancing the needs of the people with those of nature is the basic challenge. Through observations and discussion with interested individuals and agencies, many suggestions for environmental enhancement of the System have been received and are being implemented by

the Corps. The adaptive management process discussed in the Master Manual will provide additional focus on this effort, and, through implementation of the actions developed and tested through this process, Missouri River ecosystem restoration will occur.

A major environmental consideration has been the effect of various regulation practices on fish and wildlife, including threatened and endangered species. Improvement of fish spawning activities by appropriate management for habitat development and subsequent spawning is an important consideration in System regulation. Suggestions have been made and adopted to the degree practical for improving migratory waterfowl habitat and hunter access along the river below the projects. Other suggestions, such as reduction of flows during the migration period so that more sandbars could be available, cannot always be implemented without serious effects on other authorized project purposes. As further suggestions are received, they will be evaluated through the adaptive management process. Another area of environmental concern is the management of project lands. Currently, the major emphasis on the development of these lands is for water-oriented recreation; however, large areas of project lands are now being managed almost exclusively for wildlife.

Fluctuating reservoir levels and releases are also a concern to many project users but are unavoidable if the projects are to serve authorized purposes. As a consequence, access to the reservoirs and river reaches may be difficult at times, fishing success may be affected, the sediment load in the river may be increased, and users of fixed boat docks may be inconvenienced. To the extent practical, considering release requirements for other authorized purposes, release fluctuations are being minimized. Improvement of the downstream water quality is another environmental consideration receiving emphasis at this time. As discussed elsewhere, relatively good quality water is stored and released from the reservoirs.

H. Historic and Cultural Properties.

As acknowledged in the 2004 Programmatic Agreement for the Operation and Management of the Missouri River Main Stem System (PA), wave action and fluctuation of reservoir pools result in erosion along the banks of the reservoirs. Shoreline erosion can have severe effects on historic and cultural sites. During periods of extended drought, additional sites become exposed as pool levels decline. The Corps will continue working with the Tribes utilizing 36 CFR Part 800 and the PA to address the exposure of these sites. The objective of a programmatic agreement is to deal "…with the potential adverse effects of complex projects or multiple undertakings…" The PA objective was to collaboratively develop a preservation program that would avoid, minimize, and/or mitigate adverse effects along the System reservoirs. All Tribes, whether signatory to the PA or not, may request government-to-government consultation on the regulation of the System and the resulting effect on historic and cultural properties and other resources. **Plate 3** shows the locations of the Tribal Reservations.

The planned preservation program for the regulation of the System is outlined by multiple stipulations in the PA. One of the stipulations, or program components, is the Five-Year Plan. This plan outlines how the Corps will accomplish its responsibilities under the PA and the National Historic Preservation Act. The "Draft Five Year Plan, dated February 2012" (see http://www.nwo.usace.army.mil/Missions/CivilWorks/CulturalResources.aspx) is currently

being implemented. The plan includes inventory, testing and evaluation, mitigation, and other specific activities that will allow the Corps to avoid, minimize, and/or mitigate the adverse effects to cultural sites on Corps lands within the System. Two critical components of the Five-Year Plan are applicable monitoring and mitigation, which are briefly discussed in the following paragraphs.

First, a collaboratively developed plan, titled "Final Cultural Resource Monitoring Plan, date June 2014" (see Cultural Resources link in previous paragraph) is in place. This monitoring plan outlines the sites that require monitoring and specifies a frequency for monitoring. The Corps is strategically monitoring sites, including those sites within the potential operating pool elevations, to document the effects of the regulation of the System. Specific sites are identified in the draft Monitoring and Enforcement Plan for the monitoring team, comprised of Corps rangers and Tribal monitors, to visit and document impacts. This focused monitoring will result in more accurate data on the current impacts to sites along the river plus it will assist in the identification of sites for mitigation.

Second, mitigation or protection of sites that are being adversely impacted continues. The annual report is available online (see Cultural Resources link in previous paragraph). In addition, the Corps completed a contract to develop an erosion model that will compare modeling data against actual erosion data, collected by the monitoring team, to assist in the prioritization of sites for protection. Work on the erosion model was completed in June 2011.

Results expected from the proposed monitoring and mitigation actions include more accurate horizontal and vertical data on existing cultural sites, detailed impact data, proactive protection and preservation of sites.

USACE Mainstem Project
USACE Tributary Project
USBR SECTION 7 PROJECT
☆ State Capitol
-------- District Boundary

Missouri River Basin

U.S. ARMY ENGINEERS, NORTHWESTERN DIVISION
CORPS OF ENGINEERS, OMAHA, NEBRASKA
AUGUST 2011

PLATE 1. Missouri River Basin Map.

Summary of Engineering Data -- Missouri River Mainstem System

Item No.	Subject	Fort Peck Dam - Fort Peck Lake	Garrison Dam - Lake Sakakawea	Oahe Dam - Lake Oahe
1	Location of Dam	Near Glasgow, Montana	Near Garrison, ND	Near Pierre, SD
2	River Mile - 1960 Mileage	Mile 1771.5	Mile 1389.9	Mile 1072.3
3	Total & incremental drainage areas in square miles	57,500	181,400 (2) 123,900	243,490 (1) 62,090
4	Approximate length of full reservoir (in valley miles)	134, ending near Zortman, MT	178, ending near Trenton, ND	231, ending near Bismarck, ND
5	Shoreline in miles (3)	1520 (elevation 2234)	1340 (elevation 1837.5)	2250 (elevation 1607.5)
6	Average total & incremental inflow in cfs	10,200	25,600 15,400	28,900 3,300
7	Max. discharge of record near damsite in cfs	137,000 (June 1953)	348,000 (April 1952)	440,000 (April 1952)
8	Construction started - calendar yr.	1933	1946	1948
9	In operation (4) calendar yr.	1940	1955	1962
	Dam and Embankment			
10	Top of dam, elevation in feet msl	2280.5	1875	1660
11	Length of dam in feet	21,026 (excluding spillway)	11,300 (including spillway)	9,300 (excluding spillway)
12	Damming height in feet (5)	220	180	200
13	Maximum height in feet (5)	250.5	210	245
14	Max. base width, total & w/o berms in feet	3500, 2700	3400, 2050	3500, 1500
15	Abutment formations (under dam & embankment)	Bearpaw shale and glacial fill	Fort Union clay shale	Pierre shale
16	Type of fill	Hydraulic & rolled earth fill	Rolled earth filled	Rolled earth fill & shale berms
17	Fill quantity, cubic yards	125,628,000	66,500,000	55,000,000 & 37,000,000
18	Volume of concrete, cubic yards	1,200,000	1,500,000	1,045,000
19	Date of closure	24 June 1937	15 April 1953	3 August 1958
	Spillway Data			
20	Location	Right bank - remote	Left bank - adjacent	Right bank - remote
21	Crest elevation in feet msl	2225	1825	1596.5
22	Width (including piers) in feet	820 gated	1336 gated	456 gated
23	No., size and type of gates	16 - 40' x 25' vertical lift gates	28 - 40' x 29' Tainter	8 - 50' x 23.5' Tainter
24	Design discharge capacity, cfs	275,000 at elev 2253.3	827,000 at elev 1858.5	304,000 at elev 1644.4
25	Discharge capacity at maximum operating pool in cfs	230,000	660,000	80,000
	Reservoir Data (6)			
26	Max. operating pool elev. & area	2250 msl 245,000 acres	1854 msl 383,000 acres	1620 msl 386,000 acres
27	Max. normal op. pool elev. & area	2246 msl 240,000 acres	1850 msl 365,000 acres	1617 msl 362,000 acres
28	Base flood control elev & area	2234 msl 211,000 acres	1837.5 msl 308,000 acres	1607.5 msl 311,000 acres
29	Min. operating pool elev. & area	2160 msl 89,000 acres	1775 msl 125,000 acres	1540 msl 115,000 acres
	Storage allocation & capacity			
30	Exclusive flood control	2250-2246 971,000 a.f.	1854-1850 1,495,000 a.f.	1620-1617 1,107,000 a.f.
31	Flood control & multiple use	2246-2234 2,704,000 a.f.	1850-1837.5 4,211,000 a.f.	1617-1607.5 3,208,000 a.f.
32	Carryover multiple use	2234-2160 10,700,000 a.f.	1837.5-1775 12,951,000 a.f.	1607.5-1540 13,353,000 a.f.
33	Permanent	2160-2030 4,088,000 a.f.	1775-1673 4,794,000 a.f.	1540-1415 5,315,000 a.f.
34	Gross	2250-2030 18,463,000 a.f.	1854-1673 23,451,000 a.f.	1620-1415 22,983,000 a.f.
35	Reservoir filling initiated	November 1937	December 1953	August 1958
36	Initially reached min. operating pool	27 May 1942	7 August 1955	3 April 1962
37	Estimated annual sediment inflow	17,200 a.f./year 1073 yrs.	21,600 a.f./year 1,086 yrs.	14,800 a.f./year 1553 yrs.
	Outlet Works Data			
38	Location	Right bank	Right Bank	Right Bank
39	Number and size of conduits	2 - 24' 8" diameter (nos. 3 & 4)	1 - 26' dia. and 2 - 22' dia.	6 - 19.75' dia. upstream, 18.25' dia. downstream
40	Length of conduits in feet (8)	No. 3 - 6,615, No. 4 - 7,240	1529	3496 to 3659
41	No., size, and type of service gates	1 - 28' dia. cylindrical gate 6 ports, 7.6' x 8.5' high (net opening) in each control shaft	1 - 18' x 24.5' Tainter gate per conduit for fine regulation	1 - 13' x 22' per conduit, vertical lift, 4 cable suspension and 2 hydraulic suspension (fine regulation)
42	Entrance invert elevation (msl)	2095	1672	1425
43	Avg. discharge capacity per conduit & total	Elev. 2250 22,500 cfs - 45,000 cfs	Elev. 1854 30,400 cfs - 98,000 cfs	Elev. 1620 18,500 cfs - 111,000 cfs
44	Present tailwater elevation (ft msl)	2032-2036 5,000 - 35,000 cfs	1669-1677 15,000- 60,000 cfs	1422-1427 20,000-55,000 cfs
	Power Facilities and Data			
45	Avg. gross head available in feet (14)	194	161	174
46	Number and size of conduits	No. 1-24'8" dia., No. 2-22'4" dia.	5 - 29' dia., 24' penstocks	7 - 24' dia., imbedded penstocks
47	Length of conduits in feet (8)	No. 1 - 5,653, No. 2 - 6,355	1829	From 3,280 to 4,005
48	Surge tanks	PH#1: 3-40' dia., PH#2: 2-65' dia.	65' dia. - 2 per penstock	70' dia., 2 per penstock
49	No., type and speed of turbines	5 Francis, PH#1-2: 128.5 rpm, 1-164 rpm , PH#2-2: 128.6 rpm	5 Francis, 90 rpm	7 Francis, 100 rpm
50	Discharge cap. at rated head in cfs	PH#1, units 1&3 170', 2-140' 8,800 cfs, PH#2-4&5 170'-7,200 cfs	150' 41,000 cfs	185' 54,000 cfs
51	Generator nameplate rating in kW	1&3: 43,500; 2: 18,250; 4&5: 40,000	3 - 121,600, 2 - 109,250	112,290
52	Plant capacity in kW	185,250	583,300	786,030
53	Dependable capacity in kW (9)	181,000	388,000	534,000
54	Avg. annual energy, million kWh (12)	1,027	2,255	2,610
55	Initial generation, first and last unit	July 1943 - June 1961	January 1956 - October 1960	April 1962 - June 1963
56	Estimated cost September 1999 completed project (13)	$158,428,000	$305,274,000	$346,521,000

Summary of Engineering Data -- Missouri River Mainstem System

Big Bend Dam - Lake Sharpe	Fort Randall Dam - Lake Francis Case	Gavins Point Dam - Lewis & Clark Lake	Total	Item No.
21 miles upstream Chamberlain, SD	Near Lake Andes, SD	Near Yankton, SD		1
Mile 987.4	Mile 880.0	Mile 811.1		2
249,330 (1) 5,840	263,480 (1) 14,150	279,480 (1) 16,000		3
80, ending near Pierre, SD	107, ending at Big Bend Dam	25, ending near Niobrara, NE	755 miles	4
200 (elevation 1420)	540 (elevation 1350)	90 (elevation 1204.5)	5,940 miles	5
28,900	30,000 1,100	32,000 2,000		6
440,000 (April 1952)	447,000 (April 1952)	480,000 (April 1952)		7
1959	1946	1952		8
1964	1953	1955		9
1440	1395	1234		10
10,570 (including spillway)	10,700 (including spillway)	8,700 (including spillway)	71,596	11
78	140	45	863 feet	12
95	165	74		13
1200, 700	4300, 1250	850, 450		14
Pierre shale & Niobrara chalk	Niobrara chalk	Niobrara chalk & Carlile shale		15
Rolled earth, shale, chalk fill	Rolled earth fill & chalk berms	Rolled earth & chalk fill		16
17,000,000	28,000,000 & 22,000,000	7,000,000	358,128,000 cu. yds	17
540,000	961,000	308,000	5,554,000 cu. yds.	18
24 July 1963	20 July 1952	31 July 1955		19
Left bank - adjacent	Left bank - adjacent	Right bank - adjacent		20
1385	1346	1180		21
376 gated	1000 gated	664 gated		22
8 - 40' x 38' Tainter	21 - 40' x 29' Tainter	14 - 40' x 30' Tainter		23
390,000 at elev 1433.6	620,000 at elev 1379.3	584,000 at elev 1221.4		24
270,000	508,000	345,000		25
1423 msl 62,000 acres	1375 msl 102,000 acres	1210 msl 29,000 acres	1,206,000 acres	26
1422 msl 60,000 acres	1365 msl 94,000 acres	1208 msl 25,000 acres	1,146,000 acres	27
1420 msl 58,000 acres	1350 msl 76,000 acres	1204.5 msl 21,000 acres	984,000 acres	28
1415 msl 51,000 acres	1320 msl 36,000 acres	1204.5 msl 21,000 acres	437,000 acres	29
1423-1422 61,000 a.f.	1375-1365 986,000 a.f.	1210-1208 54,000 a.f.	4,674,000 a.f.	30
1422-1420 118,000 a.f.	1365-1350 1,306,000 a.f.	1208-1204.5 79,000 a.f.	11,626,000 a.f.	31
	1350-1320 1,532,000 a.f.		38,536,000 a.f.	32
1420-1345 1,631,000 a.f.	1320-1240 1,469,000 a.f.	1204.5-1160 295,000 a.f.	17,592,000 a.f.	33
1423-1345 1,810,000 a.f.	1375-1240 5,293,000 a.f.	1210-1160 428,000 a.f.	72,428,000 a.f.	34
November 1963	January 1953	August 1955		35
25 March 1964	24 November 1953	22 December 1955		36
3,445 a.f./year 525 yrs.	15,800 a.f./year 334 yrs.	2,700 a.f./year 159 yrs.	75,545	37
	Left Bank			38
None (7)	4 - 22' diameter	None (7)		39
	1013			40
	2 - 11' x 23' per conduit, vertical lift, cable suspension			41
1385 (11)	1229	1180 (11)		42
	Elev 1375			43
1351-1355(10) 25,000-100,000 cfs	32,000 cfs - 128,000 cfs 1228-1237 10,000-60,000 cfs	1153-1161 15,000-60,000 cfs		44
70	117	48	764 feet	45
None: direct intake	8 - 28' dia., 22' penstocks	None: direct intake		46
	1,074		55,083	47
None	59' dia, 2 per alternate penstock	None		48
8 Fixed blade, 81.8 rpm	8 Francis, 85.7 rpm	3 Kaplan, 75 rpm	36 units	49
67' 103,000 cfs	112' 44,500 cfs	48' 36,000 cfs		50
67,275 (15)	40,000	44,100		51
517,470	320,000	132,300	2,524,350 kw	52
497,000	293,000	74,000	1,967,000 kw	53
974	1,719	726	9,310 million kWh	54
October 1964 - July 1966	March 1954 - January 1956	September 1956 - January 1957	July 1943 - July 1966	55
$107,498,000	$199,066,000	$49,617,000	$1,166,404,000	56

Remarks

(1) Includes 4,280 square miles of non-contributing areas.
(2) Includes 1,350 square miles of non-contributing areas.
(3) With pool at base of flood control.
(4) Storage first available for regulation of flows.
(5) Damming height is height from low water to maximum operating pool. Maximum height is from average streambed to top of dam.
(6) Based on latest available storage data.
(7) River regulation is attained by flows over low-crested spillway and through turbines.
(8) Length from upstream face of outlet or to spiral case.
(9) Based on 8th year (1961) of drought drawdown (From study 8-83-1985).
(10) Affected by level of Lake Francis case. Applicable to pool at elevation 1350.
(11) Spillway crest.
(12) 1967-2017 Average
(13) Source: Annual Report on Civil Works Activities of the Corps of Engineers. Extract Report Fiscal Year 1999.
(14) Based on Study 8-83-1985
(15) 67,275 kW on per unit basis 64,684 kW on facility basis

Corps of Engineers, U.S. Army
Compiled by
Northwestern Division
Missouri River Region
August 2018

Tribal Lands of the Missouri River Basin

US Army Corps of Engineers ®

RESERVATIONS

1. Rocky Boy
2. Fort Belknap
3. Fort Peck
4. Fort Berthold
5. Turtle Mountain
6. Fort Totten
7. Red Lake
8. Nett Lake
9. White Earth
10. Leech Lake
11. Fond du Lac
12. Bad River
13. Lac Courte Oreilles
14. Lac du Flambeau
15. Crow
16. Northern Cheyenne
17. Standing Rock
18. Cheyenne River
19. Sisseton
20. Wind River
21. Pine RIdge
22. Rosebud
23. Lower Brule
24. Crow Creek
25. Yankton
26. Winnebago
27. Omaha
28. Potawatomi
29. Ute Mountain
30. Southern Ute
31. Flathead
32. Blackfeet
33. Santee
34. Flandreau
35. Iowa
36. Sac and Fox
37. Kickapoo

Plate 3

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