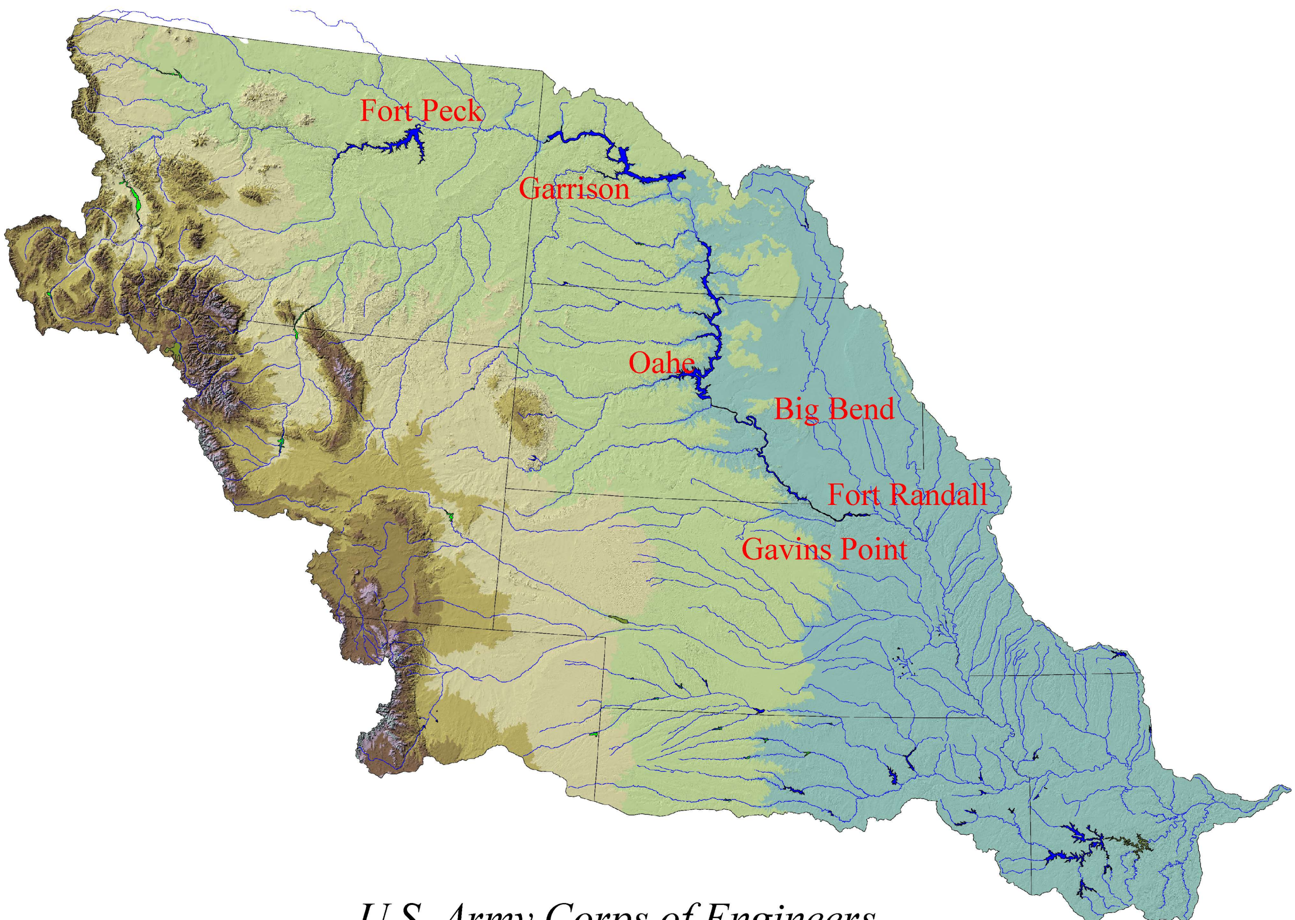
Northwestern Division

Missouri River Mainstem Reservoir System

Summary of Actual 2019 Regulation

Missouri River Basin



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

May 2020

Missouri River Mainstem Reservoir System

Summary of Actual 2019 Regulation

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LIST OF ABBREVIATIONS AND ACRONYMS

AOP	annual operating plan
AF	acre-feet
cfs	cubic feet per second
BIA	Bureau of Indian Affairs
consultation	government-to-government consultation
CPFLP	coldwater permanent fish life propagation
CY	calendar year (January 1 to December 31)
DMS	Data Management System
deg C	degrees Celsius
deg F	degrees Fahrenheit
EA	Environmental Assessment
ENSO	El Niño Southern Oscillation
EOM	end of month
Five Year Plan	Cultural Resources Program Five Year Plan
FTT	flow to target
HPRCC	High Plains Regional Climate Center
kAF	thousand acre-feet
kW	kilowatt
kWh	kilowatt hour
M	million
MAF	million acre-feet
Master Manual	Missouri River Mainstem Reservoir System Master Water Control Manual
MGD	million gallons per day
μg/l	micrograms per liter
mg/l	milligrams per liter
MRNRC	Missouri River Natural Resources Committee
MRBWM	Missouri River Basin Water Management
MV	motor vessel
MVD	Corps' Mississippi Valley Division
MW	megawatt
MWh	megawatt hour
M&I	municipal and industrial
NDEQ	Nebraska Department of Environmental Quality
NDMC	National Drought Mitigation Center
ND-SWC	North Dakota State Water Commission
NHPA	National Historic Preservation Act
NOAA-CPC	National Oceanic and Atmospheric Administration - Climate Prediction Center
NOAA-NCDC	National Oceanic and Atmospheric Administration - National Climatic Data Center
NOAA-NLDAS	National Oceanic and Atmospheric Administration - North-American Land Data Assimilation Systems
NOAA-NWS	National Oceanic and Atmospheric Administration - National Weather Service

LIST OF ABBREVIATIONS AND ACRONYMS (cont'd)

NOHRSC	National Operational and Hydrologic Remote Sensing Center
NOW Data	NOAA Online Weather Data
NRCS-SNOTEL	Natural Resources Conservation Service SNOwpack TELemetry
NWD	Corps' Northwestern Division
NWK	Corps' Kansas City District
NWO	Corps' Omaha District
OPPD	Omaha Public Power District
PA	2004 Programmatic Agreement
plover	piping plover
P-S MBP	Pick-Sloan Missouri Basin Program
RM	river mile
SCAN	Soil Climate Analysis Network
SD GFP	South Dakota Game Fish and Parks
SHPO	State Historic Preservation Officer
SNODAS	Snow Data Assimilation System
SR	steady release
SWE	snow water equivalent
System	Missouri River Mainstem Reservoir System
tern	interior least tern
THPO	Tribal Historic Preservation Officer
TMDL	total maximum daily load
T&E	threatened and endangered
USBR	U.S. Bureau of Reclamation
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VERS	Visitation Estimation Reporting System
WCSC	Waterborne Commerce Statistics Center
Western	Western Area Power Administration
WPFLP	warmwater permanent fish life propagation

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. Conversely, 1.5 cfs for 24 hours is approximately 1 million gallons; therefore, 1.5 cfs is approximately 1 million gallons per day (MGD).

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.

Drought is three or more consecutive years of below-average calendar year runoff into the Missouri River above Sioux City, IA.

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.

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MISSOURI RIVER MAINSTEM RESERVOIR SYSTEM

Summary of Actual 2019 Regulation

I. FOREWORD

This document contains a summary of the actual regulation of the Missouri River Mainstem Reservoir System (System) for the 2019 Calendar Year (CY). Two other reports related to System regulation are also available, the ***System Description and Regulation*** and ***Final 2018-2019 Annual Operating Plan.*** All three reports can be obtained by contacting the Missouri River Basin Water Management Division (MRBWM), Northwestern Division, U.S. Army Corps of Engineers (Corps) at 1616 Capitol Avenue, Suite 365, Omaha, Nebraska 68102-4909, phone (402) 996-3841. The reports are also available on the MRBWM website at www.nwd-mr.usace.army.mil/rcc.

A Missouri River Basin map is presented on ***Plate 1*** and the pertinent data for the System are shown on ***Plate 2.***

The System is a runoff driven system that is operated on an annual basis. This means that, with respect to flood risk reduction measures, all water that is captured and stored in the flood control zones of the reservoirs is evacuated before the next runoff season begins. The stored water is evacuated in a manner consistent with the Missouri River Mainstem Reservoir System Master Manual (Master Manual), and aimed at managing flood risk over the entire Missouri River Basin. However, when an extreme event or record runoff occurs, and severely damages or compromises other flood control infrastructure such as levees, the MRBWM office must consider operations that address flood risk management beyond the current year. To that end, the MRBWM office considered the following actions in 2019:

June 1: The upper Basin runoff forecast for 2019 was 50.0 MAF, which is almost twice average. Tributary flows in the tributaries that enter the Missouri River below Gavins Point Dam were above average. Lower Missouri River stages were at or above flood stage from the Platte River through central Missouri, and were forecast to remain at or above flood stage for the foreseeable future. Many Missouri River levee systems from the Platte River to the mouth had been breached and/or severely damaged. While levee repairs had begun, it was highly unlikely that the Missouri River levee systems would be fully repaired before the beginning of the 2020 runoff season. With this in mind, the MRBWM office began discussions with the Omaha District and the Kansas City District as to how the Corps should best manage flood risk for the remainder of 2019 and into the beginning of the 2020 runoff season.

Three System management scenarios were considered:

Scenario 1: Releases from the System projects would be scheduled through the summer, fall and winter to start the 2020 runoff season, which begins on or about March 1, with the full 16.3 MAF of designated System flood control storage available. System releases would be made at the lowest possible rate over the longest period of time. Under this scenario, flood risk would not be transferred from one area of the Missouri River Basin to another, nor would flood risk be transferred from 2019 to 2020.

Scenario 2: Releases from the System projects would be scheduled through the summer, fall and winter to start the 2020 runoff season, which begins on or about March 1, with less than the 16.3 MAF of System flood control storage available. Simply put, this scenario would carry over flood water from 2019 into 2020. This would result in lower System releases and Missouri River stages in the summer, fall and winter during 2019. This scenario could possibly provide some ability to drain portions of the flood plain, and possibly provide an increased opportunity for levee repair. Under this scenario, flood risk would be transferred from 2019 to 2020. The amount of 2019 flood risk reduction from this scenario would be highly dependent on the precipitation that the lower Basin received during the summer and fall of 2019. Any stage reductions that would be realized by lower System releases could be negated by large precipitation events in the lower Basin, much of which is comprised of unregulated watersheds.

Scenario 3: Releases from the System projects would be scheduled through the summer, fall and winter to start the 2020 runoff season, which begins on or about March 1, with more than the 16.3 MAF of System flood control storage available. Simply put, this scenario would overdraft the System. This scenario would reduce flood risk from upper Basin runoff in 2020. Under this scenario, lower Missouri River stages would increase through the summer and fall of 2019. This scenario would increase stress on damaged and undamaged levees and delay drainage of the flood plain. This scenario would increase intra-system releases that could potentially flood low-lying areas – between Garrison and Oahe reservoirs, in the Pierre/Ft. Pierre areas, and in the Niobrara/Springfield areas – that would otherwise not be flooded under Scenario 1 or Scenario 2. This scenario would also impact the Kansas City District's ability to evacuate stored flood water from the Kansas River basin and Osage River basin reservoir systems. The increased summer and fall 2019 releases could delay the repair of damaged levees, leaving areas of the lower Basin vulnerable to flooding from local precipitation events in 2020.

June Assessment: The MRBWM office consulted with the Northwestern Division, Kansas City District and Omaha District senior leaders, levee safety officers, and emergency managers to gather input regarding the benefits and impacts of the three scenarios described above. At the time the assessment was conducted, Oahe's pool elevation was 1.5 feet into its 3-foot Exclusive Flood Control Zone and Fort Randall's pool elevation was more than 5 feet into its 10-foot Exclusive Flood Control Zone. Additionally, the Missouri River stages downstream of the System were several feet above flood stage at a number of locations and the Missouri River was experiencing significant increases in stage with nearly every precipitation event in the lower Basin. Some levee repairs had begun, but the repairs were not complete and the levees were very susceptible to damage. Based on that information, Scenario 3 was deemed unacceptable because increasing Missouri River stages would hamper ongoing levee repair efforts and put critical infrastructure (e.g., Interstate 29) at higher risk. Decreasing System releases (Scenario 2) was considered. This scenario was not implemented because of the amount of incremental runoff from unregulated watersheds entering the Missouri River below Gavins Point was so great the System releases could not be reduced enough to significantly lower flood risk, increase the rate of levee repair, or provide for drainage of the flood plain. It was determined that Scenario 1, making necessary System releases to start the 2020 runoff season with the designated flood control storage of 16.3 MAF available, was the scenario that provided the greatest amount of flood risk reduction and would best prepare the System for the 2020 runoff.

July 1: The upper Basin runoff forecast for 2019 was 49.9 MAF. Tributary flows in the tributaries that enter the Missouri River below Gavins Point Dam remained above average. Lower Missouri River stages remained at or above flood stage from the Platte River through central Missouri, and were forecast to remain at or above flood stage for the foreseeable future. The Omaha and Kansas City Districts had made some progress with Missouri River levee repairs. However, most of the breached and/or damaged levees remained unrepaired and the completed repairs remained very vulnerable to damage.

July Assessment: In early July, the MRBWM office again consulted with the Northwestern Division, Kansas City District and Omaha District senior leaders, levee safety officers, and emergency managers to gather input as to the benefits and impacts of the three scenarios described above. At that time, the lower Missouri River stages were still several feet above flood stage at a number of locations. The Missouri River continued to experience significant stage increases with nearly every precipitation event in the lower Basin. Again, Scenario 3 was deemed unacceptable because it would increase Missouri River stages, hamper ongoing levee repair efforts, and put critical infrastructure at risk. Decreasing System releases (Scenario 2) was considered. Similar to the June assessment, the runoff from unregulated tributaries that enter the Missouri River below Gavins Point Dam remained very high. Furthermore, total System storage on July 1 was 68.0 MAF, 0.3 MAF above the base of the Exclusive Flood Control Zone, and had not yet peaked. With the System storage in this position, decreasing System releases would have increased flood risk in the upper Basin. It was determined that Scenario 1, making necessary System releases to start the 2020 runoff season with the designated flood control storage of 16.3 MAF available, continued to be the scenario that provided the greatest amount of flood risk reduction and would best prepare the System for the 2020 runoff.

August 1: The upper Basin runoff forecast for 2019 was 52.9 MAF. As was the case on July 1, tributary flows in the tributaries that enter the Missouri River below Gavins Point Dam remained above average. Lower Missouri River stages remained at or above flood stage from the Platte River through central Missouri, and were forecast to remain at or above flood stage for the foreseeable future. The Omaha and Kansas City Districts had made some progress with Missouri River levee repairs. However, most of the breached and/or damaged levees remained unrepaired and the completed repairs remained very vulnerable to damage.

August Assessment: The increased runoff forecast of 3.0 MAF from July 1 (49.9 MAF) to August 1 (52.9 MAF) severely limited the ability to overdraft the reservoir System (Scenario 3). Additionally, it was evident that the damaged levees were not going to be fully repaired before the beginning of the 2020 runoff season. It was determined that implementing Scenario 2 would provide little or no flood risk reduction benefits in 2019 and would transfer a considerable amount of risk into 2020 for the entire Missouri River Basin. It was determined that Scenario 1, making necessary System releases to start the 2020 runoff season with the designated flood control storage of 16.3 MAF available, continued to be the scenario that provided the greatest amount of flood risk reduction and would best prepare the System for the 2020 runoff.

II. REVIEW OF REGULATION – JANUARY-DECEMBER 2019

A. General

This report summarizes the System regulation as it pertains to all eight congressionally-authorized purposes. During 2019 the System was regulated in accordance with the Master Manual and the applicable provisions of the Final 2018-19 Annual Operating Plan (AOP), which was made available for review and comment by representatives of state and federal agencies, Tribes, the general public, and specific interest groups. For the purposes of this report, the upper Missouri River Basin (upper Basin) is the Missouri River Basin above Sioux City, IA and the lower Missouri River Basin (lower Basin) is the Missouri River Basin from Sioux City, IA to the mouth.

B. Precipitation and Water Supply Available in 2019

Near-record 2019 runoff in the Missouri River Basin was caused by a series of hydrologic and weather events that occurred during the entire calendar year. The hydrologic factors that most influenced 2019 runoff were wet antecedent soil moisture conditions, deeply frozen soil throughout the Missouri River Basin in early March, heavy plains snowpack in the upper Basin, and a series of large precipitation events, most notably the winter storm referred to as the 'bomb cyclone'. The 'bomb cyclone' generated heavy precipitation in Nebraska, southeastern South Dakota and western Iowa from March 13-15 and was accompanied by rapidly warming temperatures that melted several inches of plains snow water equivalent (SWE) over wet, frozen soil. The combination of events resulted in record flooding on a number of Missouri River Basin tributaries in Nebraska, South Dakota and Iowa, and on several locations of the Missouri River.

1. 2018 Precipitation and Water Supply

The 2018 unregulated runoff volume for the upper Basin above Sioux City, IA totaled 42.1 million acre-feet (MAF), which is 166 percent of average, based on the historical period of 1898-2017. The 2018 upper Basin runoff was, at that time, the third highest runoff in 121 years of record-keeping, exceeded only in 1997 (49.0 MAF) and 2011 (61.0 MAF). Precipitation and mountain snowpack were well-above average during 2018. The higher-than-average precipitation, shown by the annual precipitation rankings in ***Figure 1***, occurred primarily in the states of South Dakota, Nebraska, Iowa, Kansas and Missouri. Precipitation rankings in Montana, North Dakota and Wyoming were Near Average, while South Dakota was ranked in the Above Average category. Nebraska and Iowa were ranked Much Above Average.

2. Soil Conditions

As a result of the above-average 2018 precipitation, particularly during the fall, soil moisture conditions in the upper Basin were wetter than normal on December 1, 2018 per the National Oceanic and Atmospheric Administration (NOAA) North American Land Data Assimilation System (NLDAS) Ensemble Mean total column soil moisture percentile shown in ***Figure 2***. A soil moisture ranking at the 50th percentile indicates soil conditions are in the middle of the distribution or normal, while a high soil moisture ranking (70th to 98th percentile) are above normal. Soil moisture ranked in the 90th to 98th percentile (wetter than normal) in much of Montana, northern Wyoming, northern Nebraska, southeastern South Dakota, and northern Iowa at the end of 2018. Soil moisture was also much wetter than normal in the lower Basin in Kansas and southern Nebraska. Soil moisture in North Dakota and much of central and northern South Dakota was near normal on December 1, 2018.

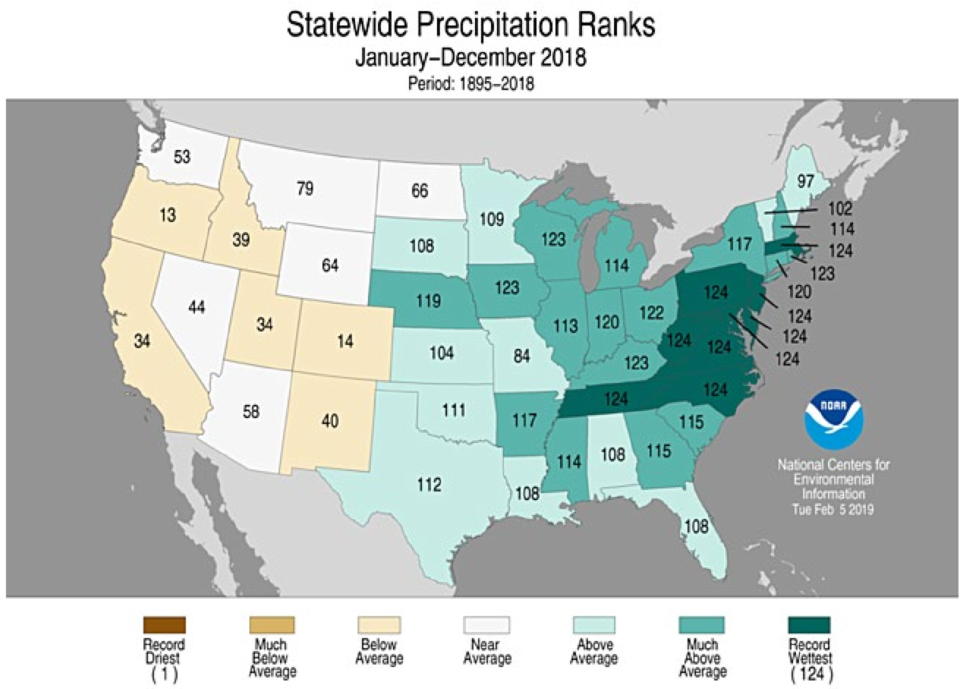


Figure 1. January-December 2018 Statewide Precipitation Ranks (Source: NOAA).

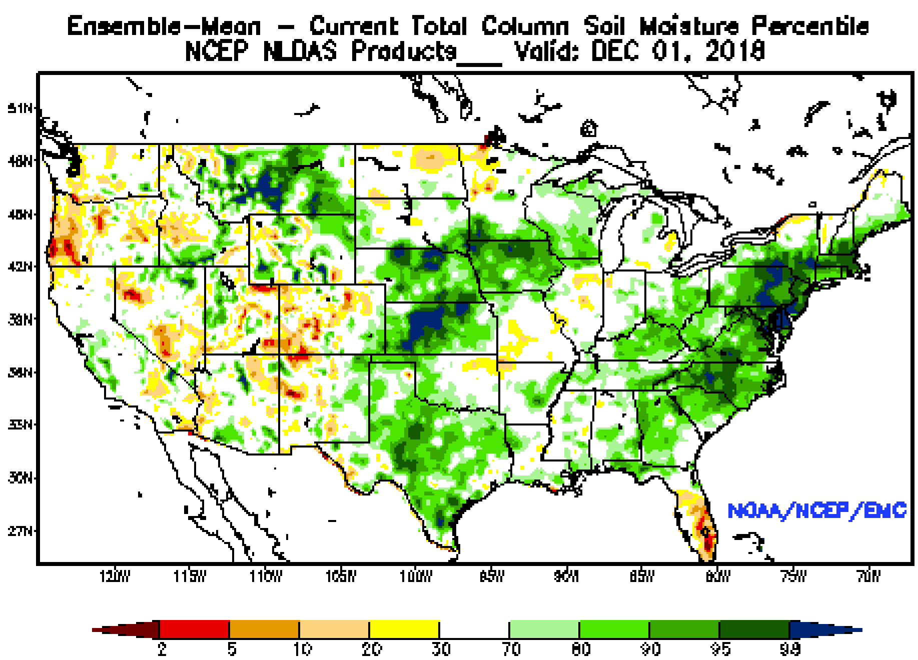


Figure 2. Soil moisture percentile ranking, December 1, 2018. Source: NOAA NLDAS.

Fall soil moisture is significant in its relation to upper Basin spring runoff. During the onset of the winter, much of this moisture is frozen in the soil, creating an impermeable barrier that snowmelt and rainfall cannot infiltrate. Soil moisture typically does not change much during the winter. Simply put, high fall soil moisture translates to high soil moisture conditions in the spring. The upper Basin soil moisture condition in early March 2019 was similar to the condition on December 1, 2018 (see ***Figure 3***). The NOAA NLDAS soil moisture percentile ranking on March 2, 2019 indicated wetter-than-normal soil conditions in Montana, northern Wyoming, southern South Dakota, Nebraska, Iowa and Kansas. Soil moisture conditions in North Dakota and much of South Dakota were near normal (30th to 70th percentile).

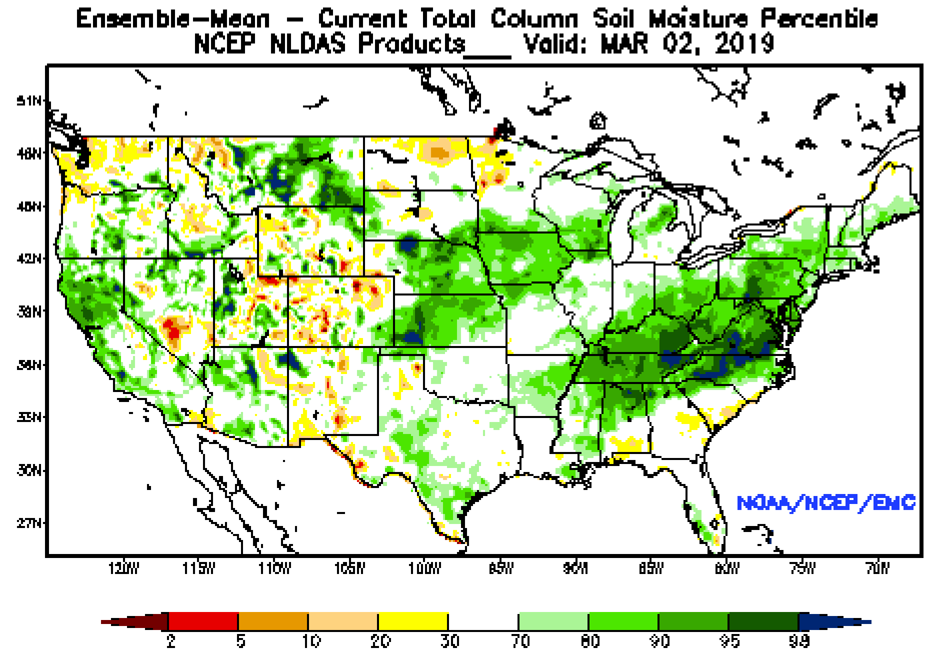


Figure 3. Soil moisture percentile ranking, March 2, 2019. Source NOAA NLDAS.

Soil frost depth is another important runoff factor as snow begins to melt. Frost depth (see ***Figure 4***) is the depth of frozen soil measured from the soil surface. The number reported under each location in ***Figure 4*** is the depth of frost in inches. An "M" denotes a missing value. Soil frost acts as a barrier to snowmelt and rainfall infiltration into the soil, particularly when soil moisture content is above normal. The general rule is: the deeper the depth of frost formation, the greater the barrier for water infiltration, thus the higher the runoff potential.

The frost depths reported by the National Weather Service (NWS) Missouri Basin River Forecast Center (MBRFC) indicate moderate-to-deep frost formation in the Missouri River Basin during the winter of 2019. On March 7, deeply frozen soils had developed in the upper Basin; soils were deeply frozen at nearly all locations in the Missouri River Basin. The deepest frost depth reported in ***Figure 4*** was 50 inches at Bismarck, ND (BRKN8). This was the second deepest frost formation depth, behind 52 inches in 2014, reported during the station's 10-year operation. The depth reported by the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) Soil Climate Analysis Network (SCAN) station at the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Data Center site, which is about 10 miles north of Sioux Falls, SD, was 24 inches on March 1, 2019, comparable to the frost formation depth of 23 inches reported at the Sioux Falls Foss Field (FSDS2). The 23-inch depth reported at Foss Field was the deepest frost measurement in the station's 12-year operation. Because of the extensive and deep formation of frost in the Missouri River Basin, the spring 2019 runoff potential was much higher than normal.

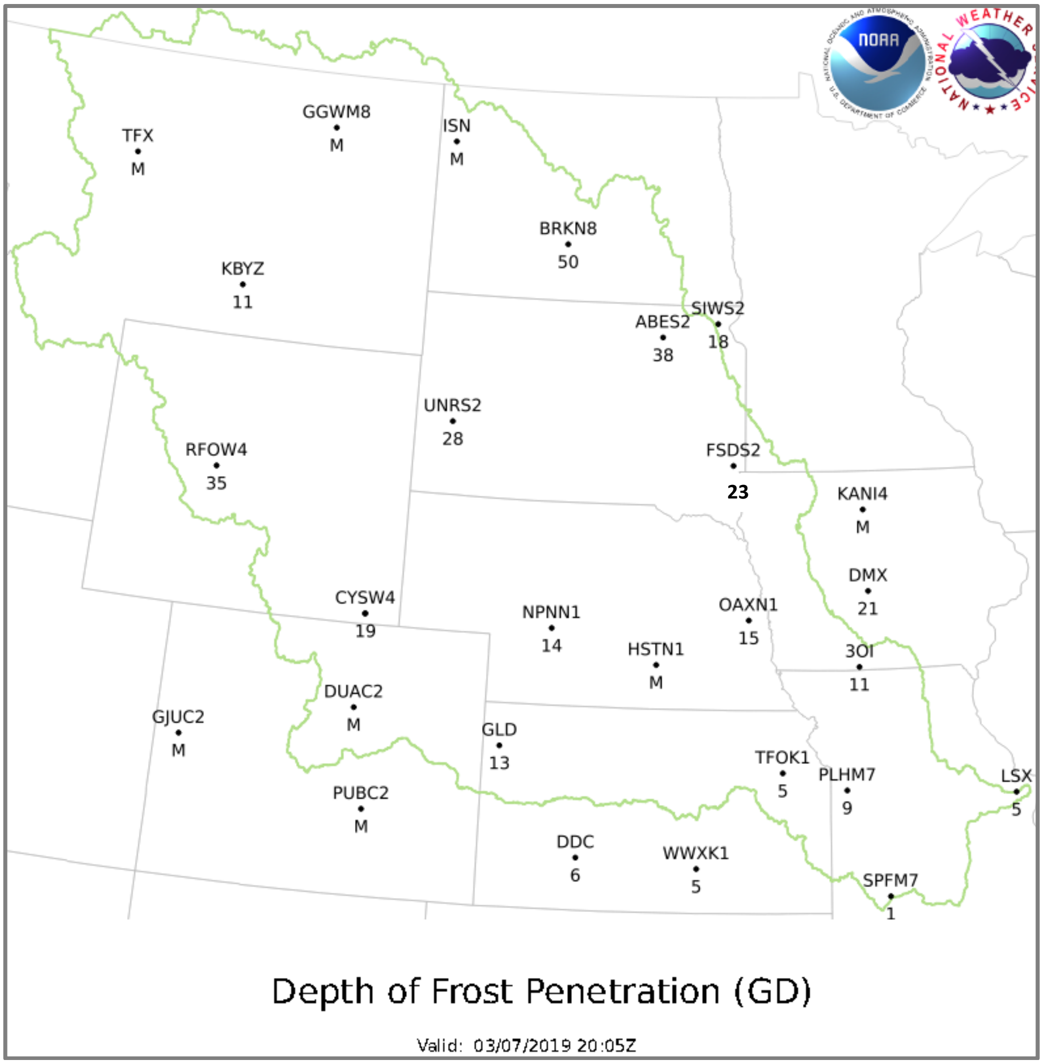


Figure 4. Frost depth (inches) penetration reported on March 7, 2019. Source: NWS MBRFC.

3. Plains Snowpack

Plains snowpack is an important source of runoff that typically melts and enters the System from mid-February to April. Historically, about 25 percent of annual upper Basin runoff occurs in March and April originating from both melting snowpack and rainfall runoff. Intermittent warm-ups in late January and February can result in plains snowmelt during those months. Plains snowpack accumulation, and more importantly the plains SWE, are used as the primary indicator of February-April runoff in the upper Basin. In addition, antecedent soil moisture conditions, observed accumulated precipitation, and observed seasonal temperature are factored into the forecasting of February-April runoff.

The seasonal plains snowpack in the upper Basin developed slowly during the first half of the 2018-19 winter, then increased rapidly during February and March. Warmer-than-normal temperatures (***Figure 5***) limited plains snowpack development from November 2018 to January in areas of eastern North Dakota and eastern South Dakota, despite above-normal precipitation in Montana, southwestern North Dakota, South Dakota and Nebraska (***Figure 6***) because the precipitation fell as rain rather than snow. Temperatures were above normal in most of the upper Basin, but normal to slightly below normal in the lower Basin.

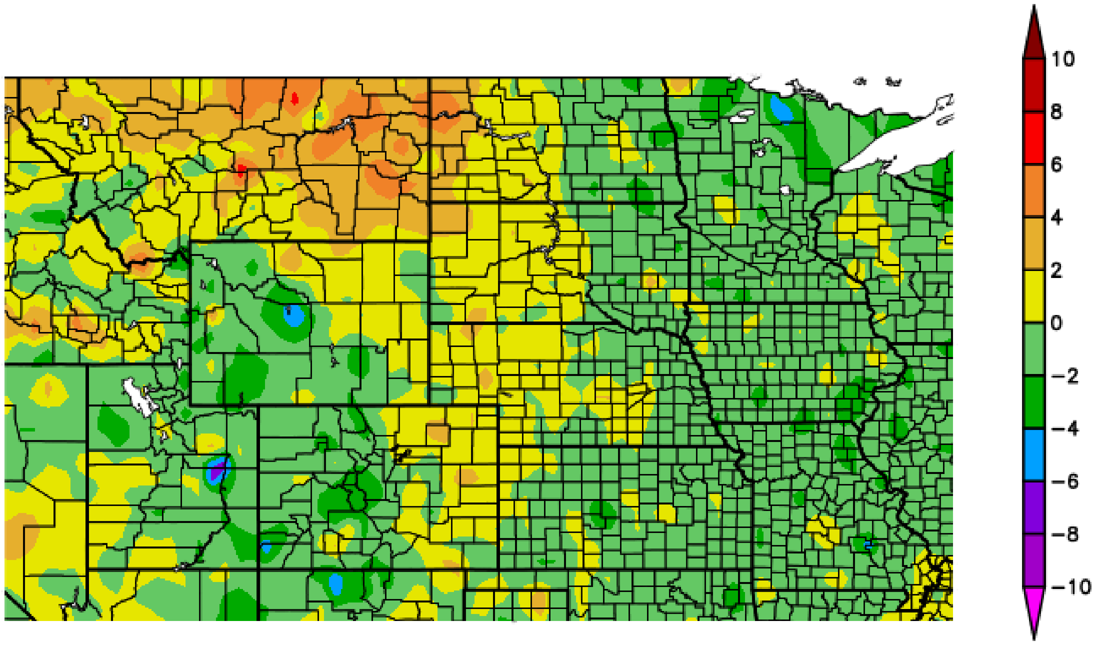


Figure 5. November 2018 – January 2019 departure from normal temperature (deg F).
Source: High Plains Regional Climate Center (HPRCC).

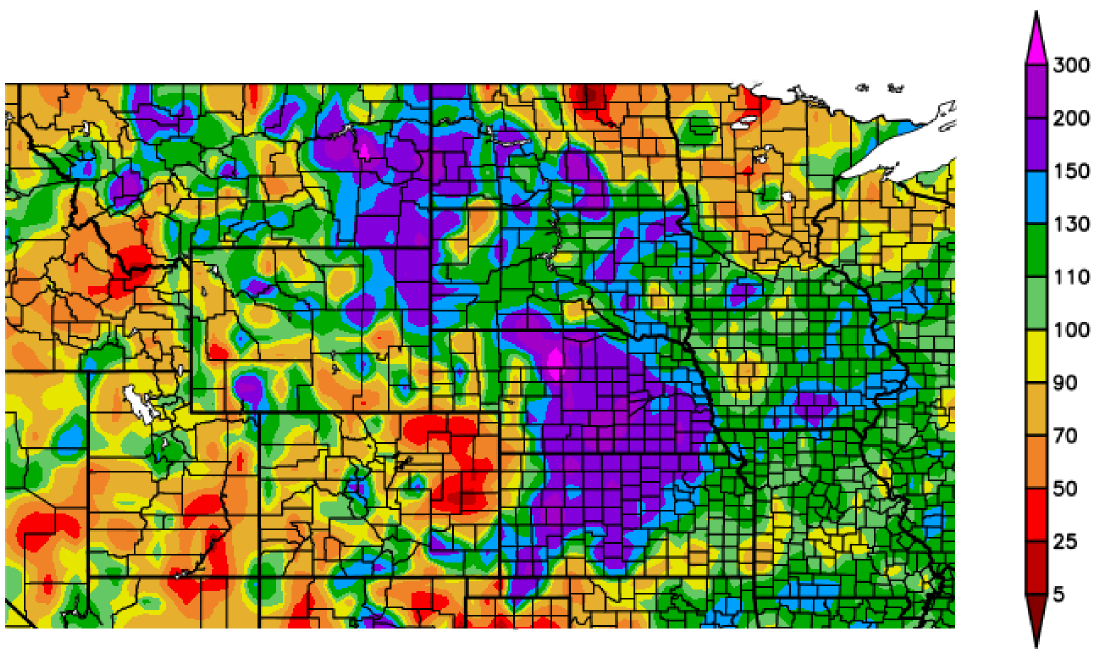


Figure 6. November 2018 – January 2019 percent of normal precipitation.
Source: HPRCC.

SWE in the Missouri River Basin on February 1, 2019, modeled by NOAA's National Operational Hydrologic Remote Sensing Center (NOHRSC), is shown in ***Figure 7***. The heaviest plains snowpack was located primarily in central and eastern North Dakota, and northern and eastern South Dakota. SWE ranged from 2 to 3 inches in much of this area and 3 to 4 inches in the deepest areas. Much of the heavy SWE was located in the James River basin and the Big Sioux River basin, while some of it extended into the Garrison to Oahe reservoir reach. Very little snowpack was present in the Platte River basin and Niobrara River basin on February 1.

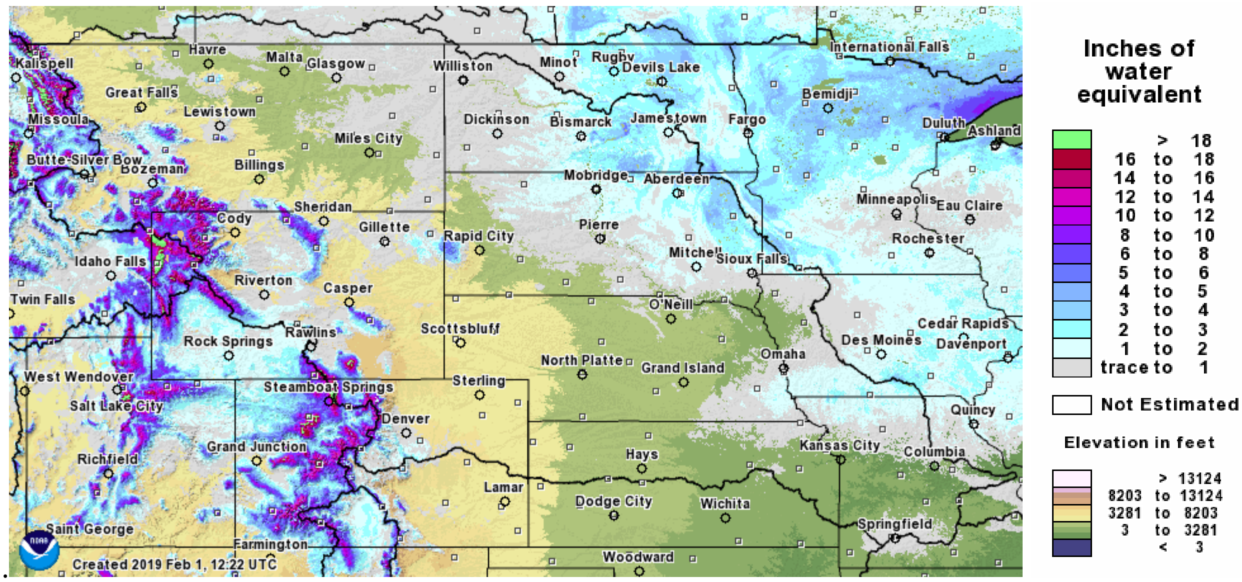


Figure 7. Modeled snow water equivalent (inches) on February 1, 2019.
Source: NOAA NOHRSC SNODAS – Interactive Snow Information

In February and March, a more active weather pattern brought well-above-average snowfall to the upper Basin, Nebraska and Iowa. Intense, cold temperatures and above-normal precipitation were major factors that caused the rapid formation of moderate-to-heavy plains SWE in the upper Basin and portions of the lower Basin. From February 1 to April 30, the temperature departures in Montana ranged from 9 to 12 degrees Fahrenheit (deg F) below normal (see ***Figure 8***), and temperature departures in the Dakotas ranged from 6 to 12 deg F below normal. Colder-than-normal temperatures also spread throughout the lower Basin, resulting in the formation of an unusually deep plains snowpack and thick river ice in February. Plains precipitation from February 1 through April 30 was well-above normal in Montana, South Dakota, northern Nebraska and northwestern Iowa (***Figure 9***).

The repeated winter storms brought near-record February snowfall to many locations in Montana, North Dakota, South Dakota and Nebraska (see ***Table 1***). February snowfall records were set in Glasgow, MT; Ashley, ND; Bison, SD; Omaha, NE; and Nebraska City, NE. Several of these locations eventually set seasonal snowfall records. February snowfall was also very heavy at most locations listed in ***Table 1***, especially in Billings, MT, which received 29.4 inches and Great Falls, MT, which received 32.3 inches. Heavy snowfall continued in March, particularly in southern North Dakota, central and eastern South Dakota, and in April in North Dakota and South Dakota. ***Table 1*** lists 2018-19 seasonal snowfall totals and the long-term average annual snowfall totals for each station. Long-term average snowfall totals for the station periods of record are provided because some stations possess record lengths too short to establish 30-year normal values. In many locations, the 2018-19 snowfall was more than two times the average amount, and in some locations almost three times the average amount.

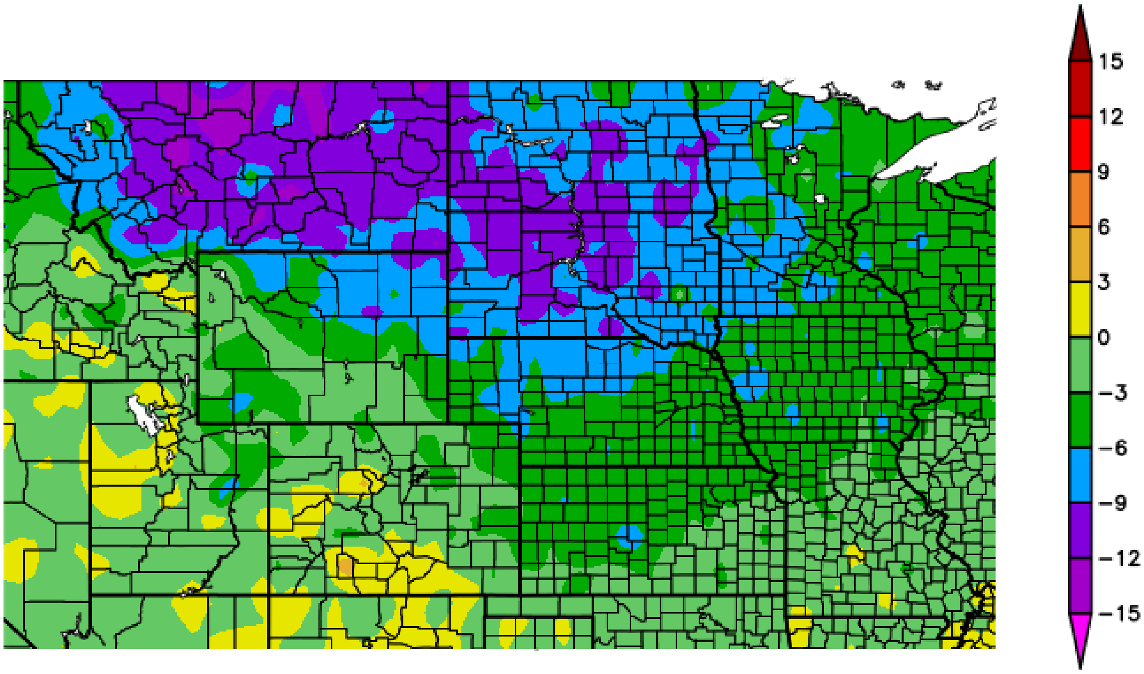


Figure 8. February – April 2019 departure from normal temperature (deg F). Source: HPRCC.

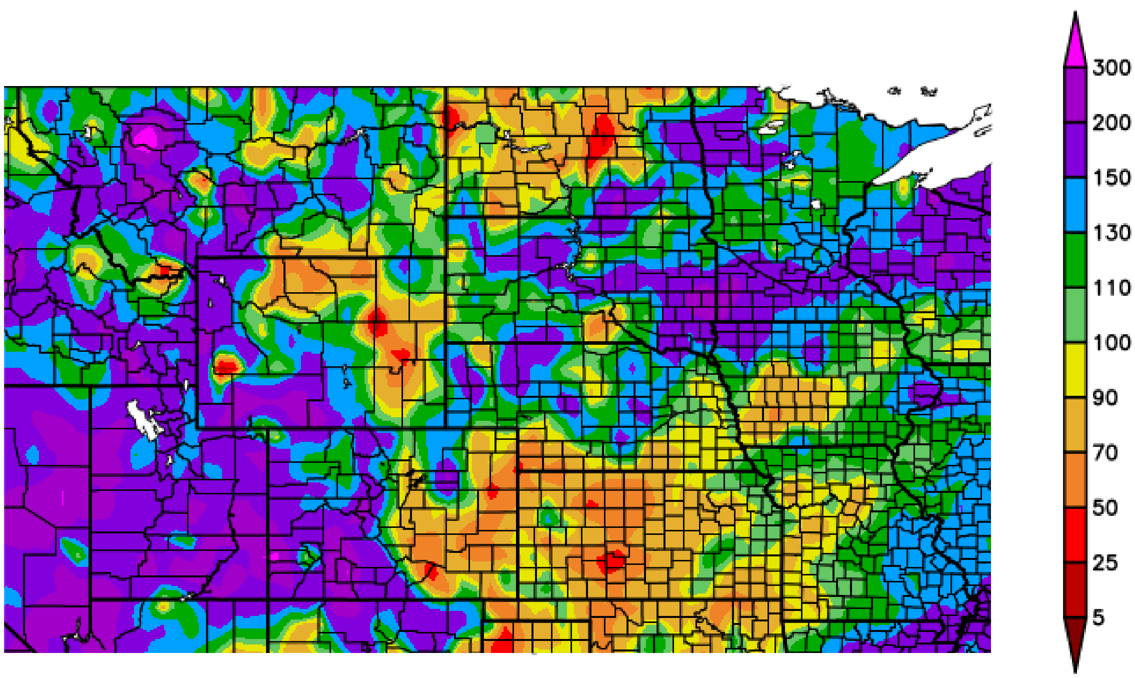


Figure 9. February – April 2019 percent of normal precipitation. Source: HPRCC.

Table 1
Missouri River Basin – 2018-19 Monthly and Seasonal Plains Snowfall Totals (inches)

Location	Dec	Jan	Feb	Mar	Apr	2018-19	Average Annual*	Maximum
Billings, MT	8.7	13.7	29.4	2.2	0.4	61.1	57.0	106.1 (2018)
Glasgow, MT	6.9	3.7	**28.2**	0.1	T	45.4	31.3	108.6 (2011)
Great Falls, MT	5.1	15.1	32.3	5.6	4.0	76.4	54.8	117.5 (1989)
Bismarck, ND	8.2	11.3	15.7	13.2	3.8	60.3	40.3	101.6 (1997)
Montpelier, ND	9.2	7.9	25.6	22.5	9.0	83.2	38.2	99.9 (1997)
Ashley, ND**	16.1	16.5	**30.6**	23.3	13.1	**110.2**	28.4	**110.2 (2019)**
Bison, SD**	11.5	7.0	**28.3**	14.0	**15.5**	**80.8**	40.5	**80.8 (2019)**
Pierre, SD	6.8	6.0	19.0	15.9	16.1	66.3	32.3	82.0 (1952)
Aberdeen, SD**	12.3	12.7	19.3	16.4	13.6	**81.1**	36.3	**81.1 (2019)**
Watertown, SD**	14.3	12.2	18.1	7.2	25.0	**81.7**	33.3	**81.7 (2019)**
Sioux Falls, SD	7.2	8.1	21.0	5.4	6.9	52.4	38.6	94.7 (1969)
Yankton, SD	17.5	3.5	13.0	4.0	4.0	48.0	29.0	70.5 (2016)
Omaha, NE	6.2	12.9	**27.0**	2.9	T	52.7	29.1	67.5 (1912)
Lincoln, NE**	5.6	9.7	23.2	6.3	T	**55.5**	26.6	**55.5 (2019)**
Nebraska City, NE**	6.0	20.0	**19.0**	5.0	0.0	**62.0**	27.3	**62.0 (2019)**
Shenandoah, IA**	3.0	16.1	19.5	3.5	0.0	**51.3**	26.2	**51.3 (2019)**

* Average annual snowfall is computed for September – May snowfall totals from the station period of record.
** Record high season snowfall total in 2018-19
Numbers highlighted in bold text are monthly or seasonal record totals.
Data source: NOAA Online Weather Data (NOWData).

By March 10, 2019, the snowfall extent and SWE, shown in ***Figure 10,*** was at its seasonal maximum. By March 10, the deepest plains snowpack was present in North Dakota and South Dakota where SWE amounts ranged from 3 to 5 inches according to the NOHRSC SNODAS model. Moderate SWE amounts ranging from 2 to 3 inches were present throughout much of Montana, western North Dakoa, southern South Dakota and Nebraska. SWE in western Iowa ranged from 2 to 4 inches.

From March 12-15, the 'bomb cyclone', described in more detail in Section II.B.5, moved across the lower Basin, bringing in warm, moist Gulf air, which fueled heavy rainfall and snow across Nebraska, southeastern South Dakota and Iowa, and heavy snow in central South Dakota and North Dakota. Overall, this large area received 4 to 7 inches of liquid water from snow melt and new precipitation, which ran off into the Missouri River and its tributaries. Snowmelt that occurred during the 'bomb cyclone' over the 72-hour period ending on March 15, 2019 is shown in ***Figure 11***.

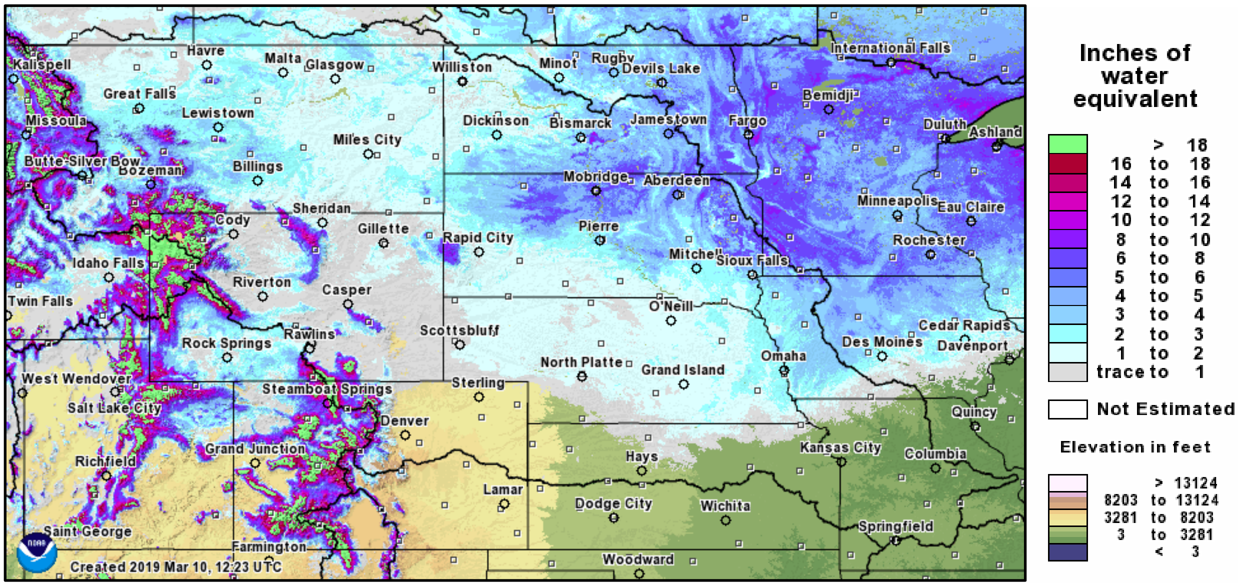


Figure 10. Modeled snow water equivalent (inches) on March 10, 2019.
Source: NOAA NOHRSC SNODAS – Interactive Snow Information

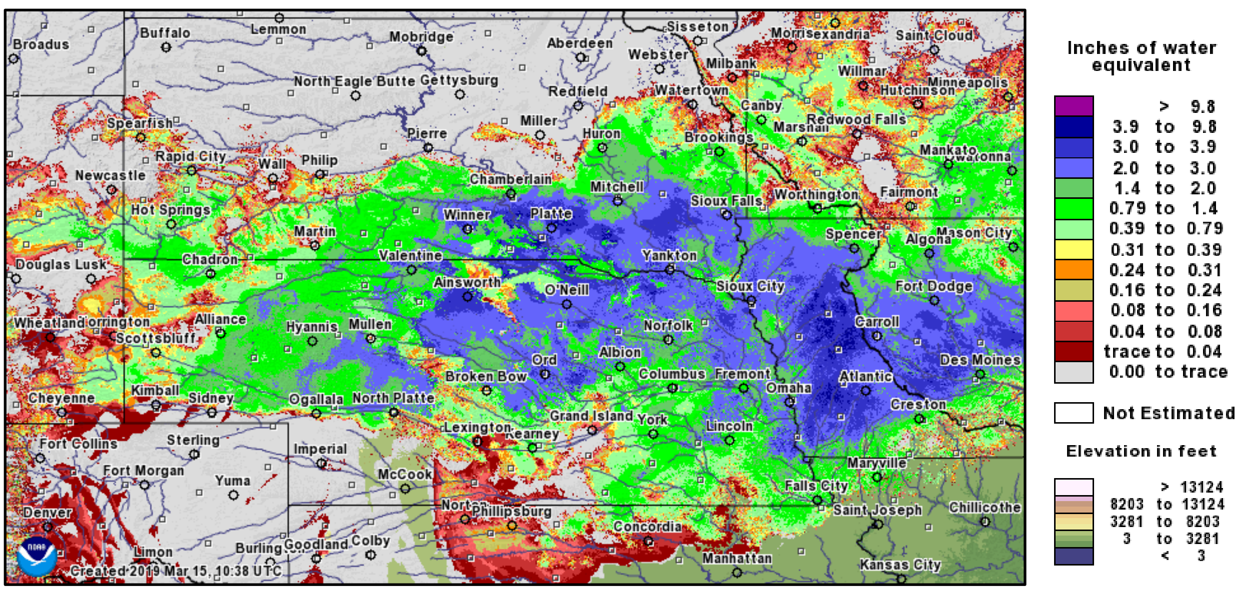


Figure 11. 72-hr modeled snow water equivalent melt (inches) on March 15, 2019.
Source: NOAA NOHRSC SNODAS – Interactive Snow Information

Following the March 12-15 'bomb cyclone', the plains SWE had increased over central and northern South Dakota and North Dakota. The NOHRSC modeled SWE map (***Figure 12***) indicated heavy SWE ranging from 4 to 5 inches over much of this area and potentially 5 to 6 inches of SWE extending from northwestern South Dakota into southern and eastern North Dakota and eastern South Dakota. The plains snow began to melt beginning in Montana and Wyoming on March 18, until much of the plains snow had melted in late March in Montana, Wyoming and western North Dakota. On March 24, the area of heavy snow in North Dakota and South Dakota, ranging from 4 to 6 inches of water equivalent, remained primarily in the

Garrison to Oahe reach, the James River basin, and the upper Big Sioux River basin. This snow melted by April 7.

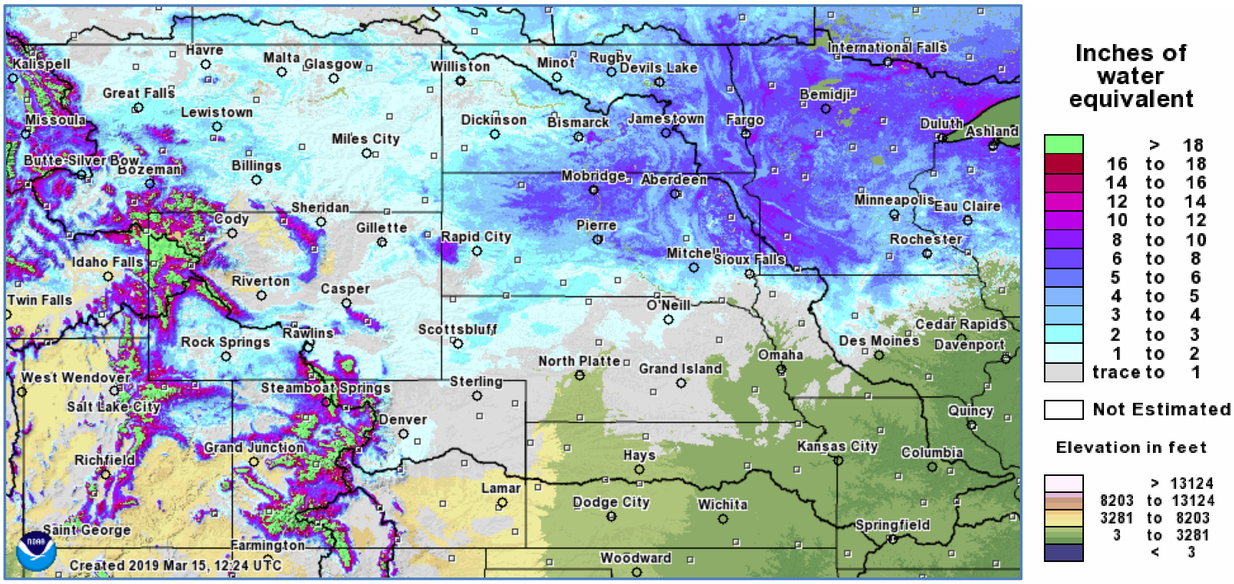


Figure 12. Modeled snow water equivalent (inches) on March 15, 2019.
Source: NOAA NOHRSC SNODAS – Interactive Snow Information

During the January-March period, volunteers for the NWD MRBWM cooperative plains snow survey made snow depth and SWE measurements approximately two times per month until the snow melted. These measurements are primarily used by the Corps and NOHRSC to monitor the accumulation and melt of plains snowpack in the upper Basin, and to verify NOAA NOHRSC modeled estimates of plains snowpack. The network of observers includes Omaha District employees (e.g., project personnel at System projects and Pipestem), NWS employees, state agencies, county emergency managers and the public. Snow measurements performed by the MRBWM cooperators are provided on the MRBWM website.

Seasonal plains snowfall totals for the winter of 2018-19, and the four previous high snowfall seasons, for locations in the plains are listed in ***Table 2***. During the 2018-19 winter, snowfall totals were well-above average in all locations in the upper Basin except Sioux City, IA, which was slightly below average. Sioux City's less-than-average snowfall total was in stark contrast to the record snowfall that occurred in Aberdeen, SD and Watertown, SD, and the second highest seasonal snowfall total in Omaha, NE. Snowfall was also above average in much of the lower Basin. Comparing the 2018-19 average of the eleven locations in ***Table 2*** to four recent high snowfall years, the winter of 2018-19 snowfall of 58.7 inches ranked as the second highest snowfall year, behind 69.3 inches in 2010-11, which was a very heavy snowfall year in the Missouri River Basin. Total March-April 2019 runoff in the upper Basin was 18.7 MAF, 318 percent of the long-term March-April runoff total average, compared to 14.1 MAF in 2011. As seen in ***Table 2***, plains snow in 2010-11 (69.3 inches) was more than 10 inches greater than 2018-19 (58.7 inches). The record magnitude of the March-April 2019 upper Basin runoff highlights the importance of the highly saturated soil moisture conditions, deeply frozen soils, and the 'bomb cyclone' in generating record spring runoff in the upper Basin, and record flooding in the lower Basin from Sioux City, IA to the mouth throughout the spring and summer of 2019.

Table 2
Missouri River Basin - Plains Snowfall Totals (inches)

Location	2009-10 Total	2010-11 Total	2012-13 Total	2017-18 Total	2018-19 Total	Average Annual*
Billings, MT	52.1	72.2	40.4	106.1**	61.1	57.0
Glasgow, MT	30.2	108.6	62.3	63.9	45.4	31.3
Great Falls, MT	77.2	108.6	76.1	104.9	76.4	54.8
Bismarck, ND	55.4	85.4	57.3	44.1	60.3	40.3
Rapid City Arpt, SD	40.8	71.1	76.7	60.1	75.8***	42.2
Aberdeen, SD**	37.8	79.3	62.8	43.2	81.1	36.3
Watertown, SD**	58.5	79.4	47.1	53.1	81.7	33.3
Sioux Falls, SD	57.1	45.1	43.3	70.4	52.4	38.6
Sioux City, IA	59.8	41.3	45.1	45.2	29.5	32.7
Omaha, NE	47.6	34.9	35.7	17.0	52.7	29.0
Kansas City, MO	44.3	36.9	31.8	7.7	29.1	20.6
Average	**51.0**	**69.3**	**52.6**	**56.0**	**58.7**	**37.8**

* Average annual snowfall is computed from the station period of record.
** Snowiest season on record.
*** Estimated with data from Rapid City NWS Weather Forecast Office (WFO)
Source: NOAA NOWData. Totals represent total snowfall from July to June of the following year.

4. Mountain Snowpack

Mountain snowpack is monitored by the USDA NRCS network of SNOwpack TELemetry (SNOTEL) stations. For purposes of monitoring the mountain snowpack and forecasting spring and summer runoff from the Rocky Mountains, average mountain snowpack expressed as inches of SWE is computed from the SNOTEL stations within the reservoir reaches above Fort Peck and from Fort Peck to Garrison. For the purposes of this report, the mountain snowpack reaches are referred to as "Fort Peck" and "Garrison". The 2018-19 mountain snowpack accumulation and melt pattern for the two reaches is illustrated in ***Figure 13***. The 2018-19 mountain SWE is described as a percent of the 1981-2010 average SWE occurring on the first day of each month. SWE accumulation for the two reaches is summarized in ***Table 3***, which contains the mountain snowpack as a percent of the seasonal average and as a percent of the average April 15 peak.

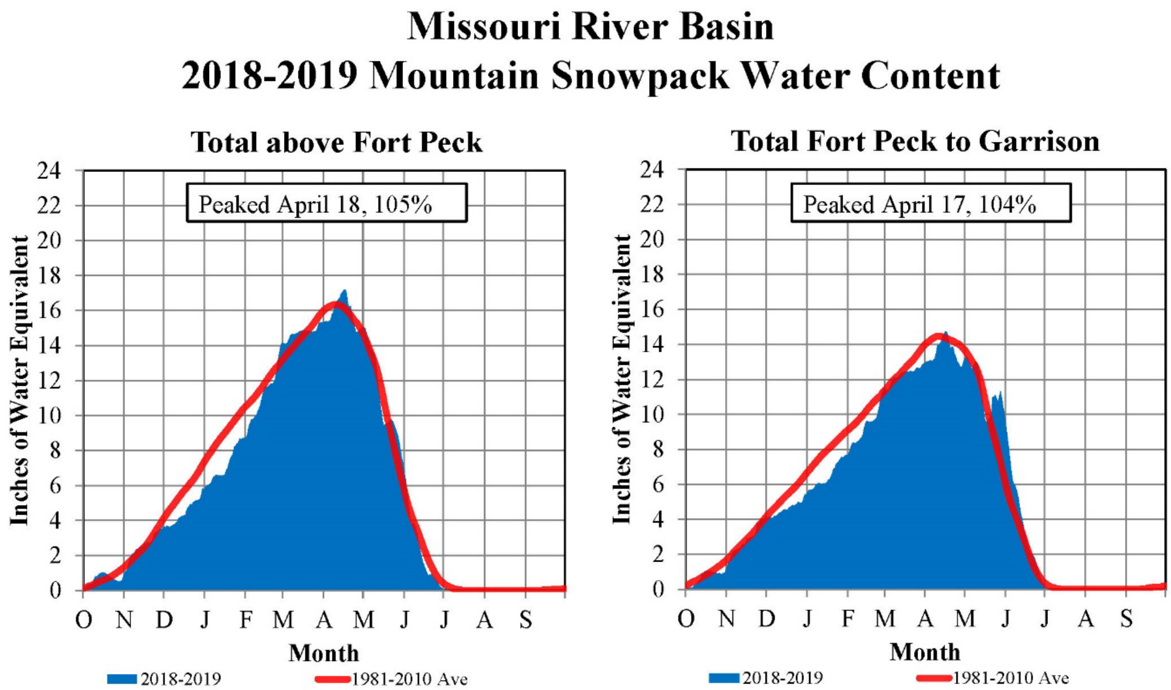


Figure 13. Missouri River Basin 2018-19 Mountain SWE.
Data Source: USDA-NRCS National Water and Climate Center.

In both reaches, the mountain SWE accumulated at near-average rates from October to the beginning of December. From December through January, warmer-than-normal temperatures in Montana and Wyoming slowed the accumulation of mountain snowpack, thus the mountain SWE was below average on January 1 and February 1. In February, increased precipitation throughout the upper Basin and below-normal temperatures increased SWE accumulation rates. By March 1, the mountain SWE was 107 percent of average in the Fort Peck reach and 101 percent of average in the Garrison reach. Mountain SWE fell below average again in March when the precipitation storm track moved more southeastward into the plains. March precipitation was well-below normal in mountainous regions of Montana and northern Wyoming. The April 1 mountain SWE was 96 percent of average in the Fort Peck reach and 92 percent of average in the Garrison reach. Above-normal April precipitation increased the mountain SWE accumulation rates. Mountain SWE peaked at 105 percent of average in the Fort Peck reach on April 18 and at 104 percent of average in the Garrison reach on April 17. The mountain snowpack normally peaks in both reaches around April 15. Mountain SWE remained above the seasonal averages in both reaches on May 1 and June 1 due to above-normal precipitation accumulations and colder-than-normal temperatures in the mountains. June brought a drier period to the mountains. By July 1, the SWE was much less than the July 1 average. All measureable mountain SWE had melted in both reaches by July 9.

Table 3
Mountain SWE Accumulation, 2019

Month	Above Fort Peck (Percent of Average)	Fort Peck to Garrison (Percent of Average)	Average Percent of Actual Peak Accumulation
January 1	79	83	37
February 1	83	85	54
March 1	107	101	83
April 1	96	92	92
Peak	April 18, 105	April 17, 104	100
May 1*	103 / 92	97 / 91	92
June 1*	119 / 41	158 / 66	54
July 1*	6 / 0	41 / 1	1
Melt-out	July 9	July 9	

*Percent of May 1, June 1 or July 1 1981-2010 average / Percent of average April 15 peak

5. Weather Conditions

a. General Weather Conditions

The upper Basin experienced record-high precipitation and Below Average temperatures during 2019, while the lower Basin received Much Above Average precipitation. January-December statewide precipitation rankings compared to the last 125 years of record are shown in ***Figure 14A*** and January-December regional precipitation rankings are shown in ***Figure 14B***. NOAA describes precipitation and temperatures in the ranking maps in reference to Average rather than Normal. With regard to precipitation, North Dakota, South Dakota and Minnesota experienced their Record Wettest year, while Nebraska experienced its third wettest year. Iowa, Kansas and Missouri experienced Much Above Average precipitation, and Montana and Wyoming experienced Above Average precipitation. Areas that received record wettest precipitation extended from southeastern Montana through southern North Dakota, northern and central South Dakota, and eastern South Dakota. Regionally, the West North Central and East North Central regions, which overlap with the upper Basin and include Nebraska, Iowa and Missouri in the lower Basin, experienced their Record Wettest years (see ***Figure 14B***). Overall, the contiguous United States experienced its second wettest year.

With regard to temperature rankings, January-December statewide and regional temperature rankings for the past 125 years are shown in ***Figure 15A*** and ***Figure 15B***, respectively. On a statewide basis, temperature rankings were Below Average in much of the Missouri River Basin including the states of Montana, North Dakota, Nebraska and Iowa. South Dakota experienced Much Below Average temperatures. Temperature rankings were Near Average in Wyoming and Kansas. The Missouri temperature ranking was Above Average.

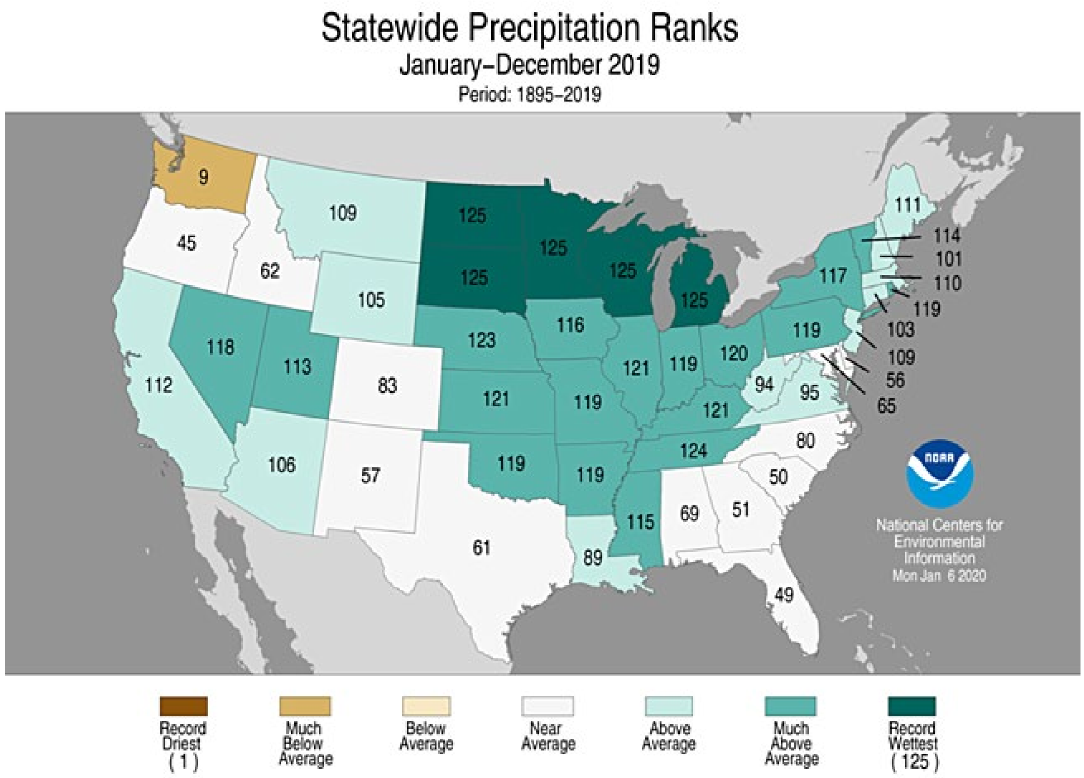


Figure 14A. January-December 2019 Statewide Precipitation Ranks (Source: NOAA).

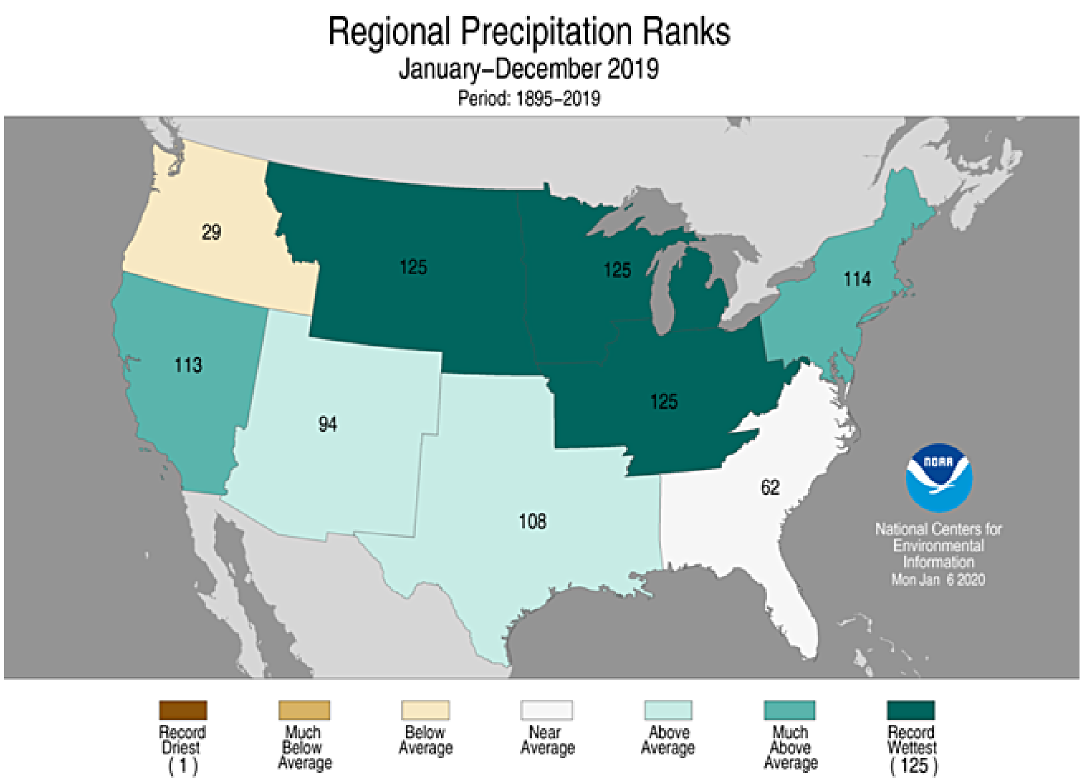


Figure 14B. January-December 2019 Regional Precipitation Ranks (Source: NOAA).

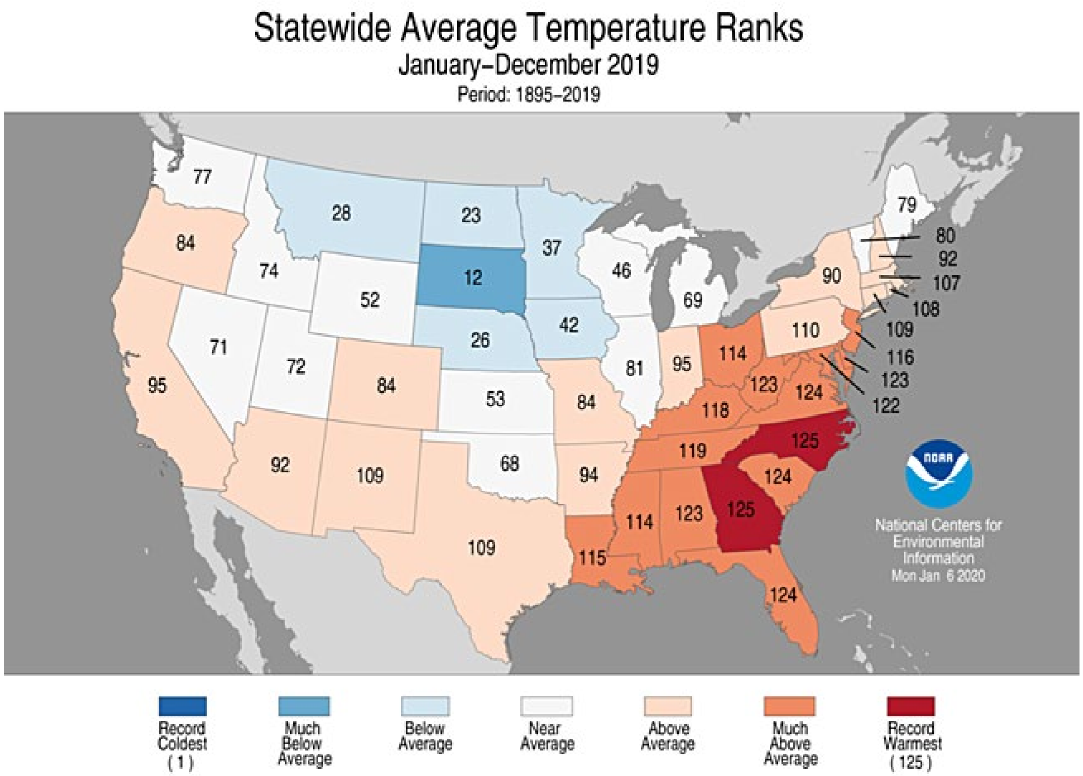


Figure 15A. January-December 2019 Statewide Temperature Ranks (Source: NOAA).

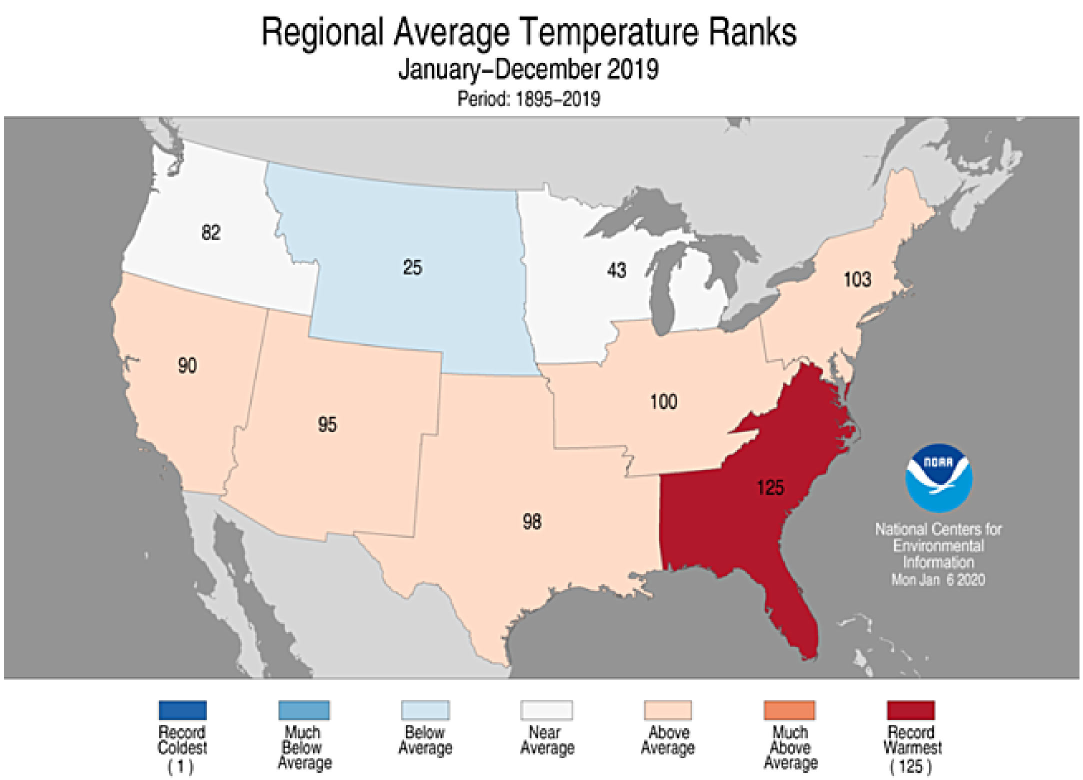


Figure 15B. January-December 2019 Regional Temperature Ranks (Source: NOAA).

Figure 16 includes the National Drought Mitigation Center's drought maps at the beginning of the four 3-month periods during 2019. During 2019, the Missouri River Basin was impacted by some localized areas of Abnormally Dry (D0) conditions in the upper Basin during the first half of 2019. By the end of 2019, drought-like conditions were not present in the Missouri River Basin. ***Figure 17***, which is referenced in the Weather Conditions section, shows percent of normal precipitation maps for each month of 2019. ***Figure 18*** shows departure from normal temperature maps for 3-month periods in 2019. These maps reference normal (median) conditions established by HPRCC based on the 1981-2010 precipitation and temperature records.

Weak El Niño conditions were present in the equatorial Pacific Ocean based on 3-month sea surface temperature anomalies from September 2018 to June 2019. El Niño is the warm phase of the El Niño Southern Oscillation Index (ENSO) describing anomalies of sea surface temperatures in the equatorial Pacific Ocean. During El Niño episodes of ENSO, there is a higher probability for warmer-than-normal temperatures during the winter months in the upper Basin; however, the observed temperatures during the winter of 2018-19 throughout the upper Basin were colder than normal. During El Niño, there is also a slight increase in the probability for above-normal precipitation, particularly in the lower Basin. Observed 2019 precipitation in the Missouri River Basin was Much Above Average to Record Wettest (***Figure 14A*** and ***14B***).

In 2019, the upper Basin runoff was 60.9 MAF, 0.1 MAF less than the record 61.0 MAF observed in 2011. As downstream conditions permitted, water stored in the System reservoir's Annual Flood Control and Multiple Use and Exclusive Flood Control zones was released throughout the summer and fall. Plots of the actual or regulated Missouri River flow versus the unregulated or natural Missouri River flow are shown in ***Figure 19A*** at Wolf Point, MT and Bismarck, ND; ***Figure 19B*** at Sioux City, IA and Omaha, NE; ***Figure 19C*** at Nebraska City, NE and Rulo, NE; ***Figure 19D*** at St. Joseph, MO and Kansas City, MO; and ***Figure 19E*** at Boonville, MO and Hermann, MO.

The following paragraphs are discussions of precipitation and temperature conditions during significant weather events of 2019. Precipitation and temperature conditions are discussed in reference to normal (median) conditions based on the 1981-2010 period of record.

b. Winter and March 'Bomb Cyclone'

The upper Basin experienced two very different weather patterns during the winter. During the first half of the winter, temperatures were relatively warm and the upper Basin received normal to above-normal precipitation through the end of January (see ***Figure 17***). During the second half of the winter the upper Basin experienced a very wet and cold period, which led to unprecedented spring runoff and record flooding throughout the entire Missouri River Basin. Near the end of January, temperatures became much colder than normal and winter storm systems repeatedly produced snowfall over the upper Basin from Montana to the Dakotas during February and March. February precipitation was more than twice normal in northwestern Wyoming, Montana, North Dakota, much of South Dakota, northwestern Iowa and eastern Nebraska. Snowfall was much greater than average in all areas of the Missouri River Basin, reaching record amounts of February snowfall in locations such as Glasgow, MT; Ashley, ND; and Omaha, NE (see ***Table 1***).

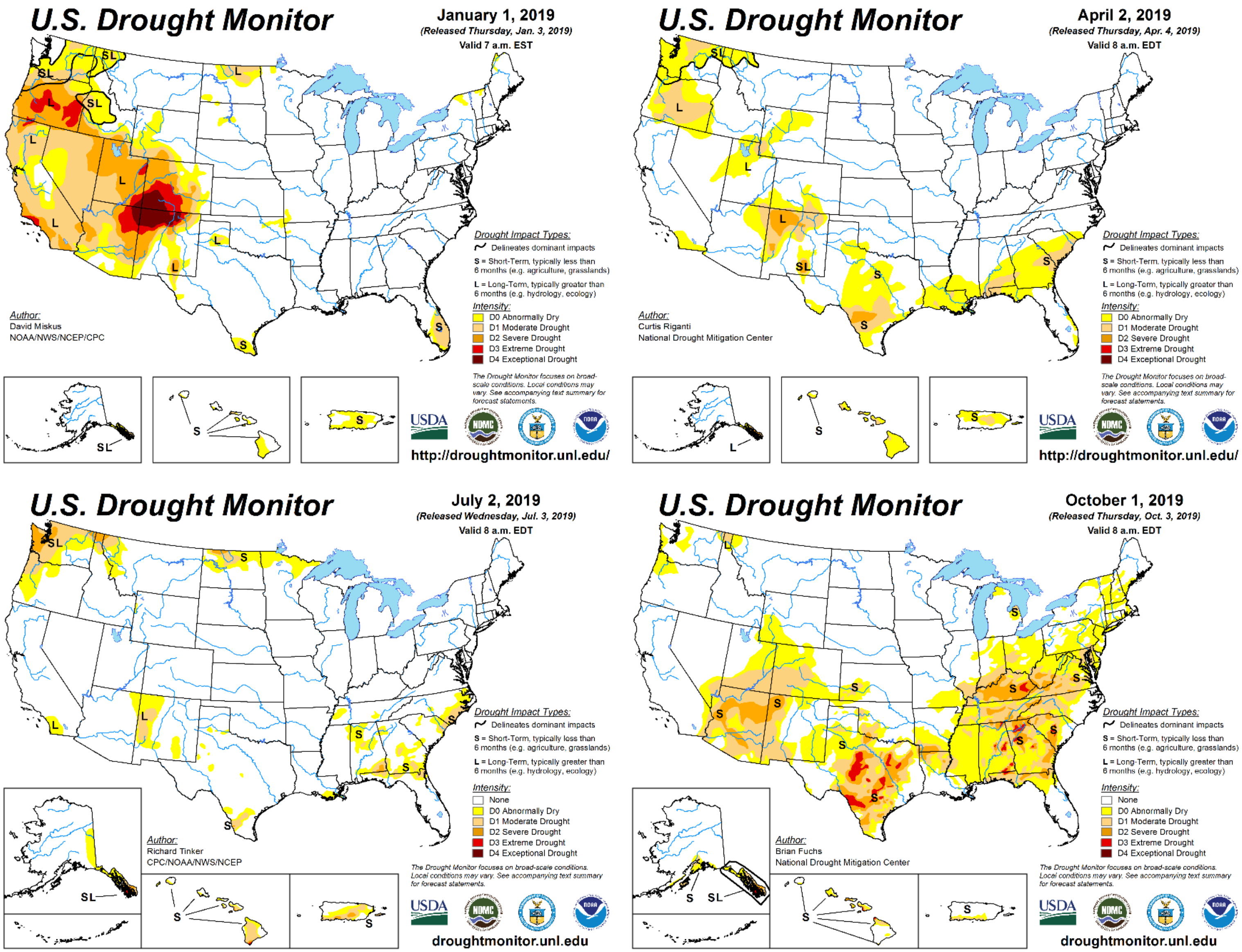


Figure 16. The National Drought Mitigation Center's drought maps for early January, April, July and October 2019.

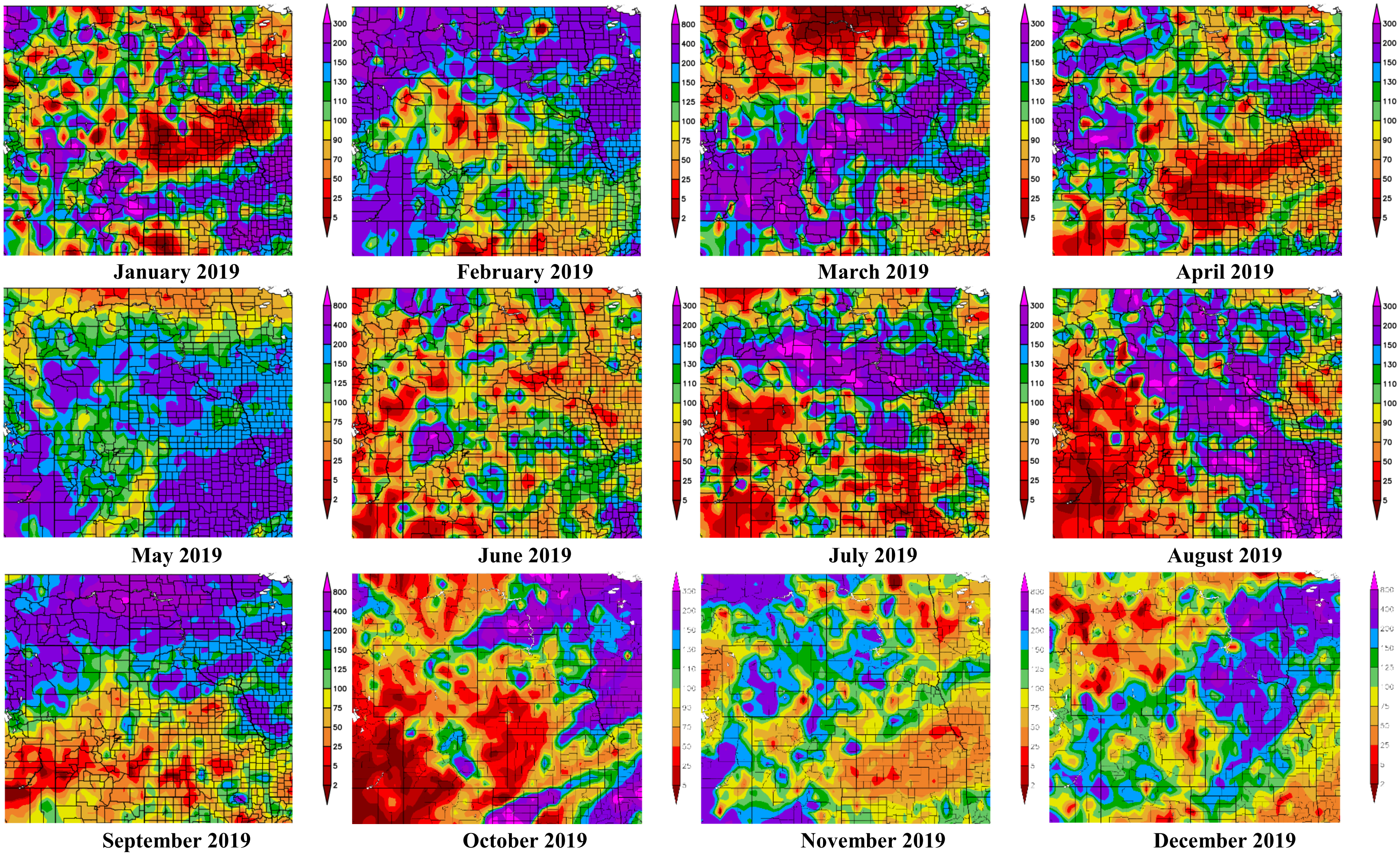


Figure 17. Percent of normal precipitation maps for 2019, by month. Reformatted from the HPRCC Climate Summary Maps.

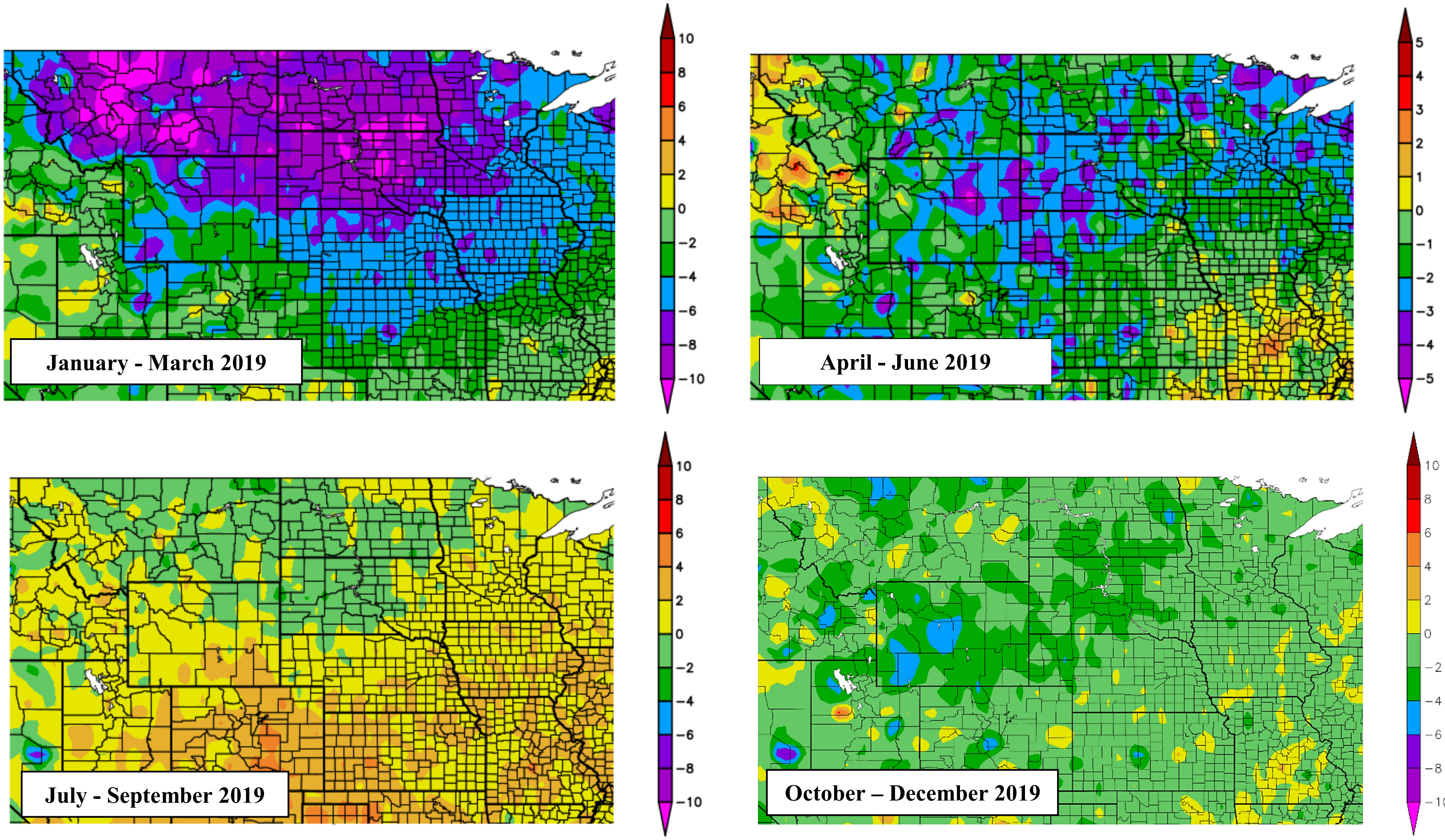
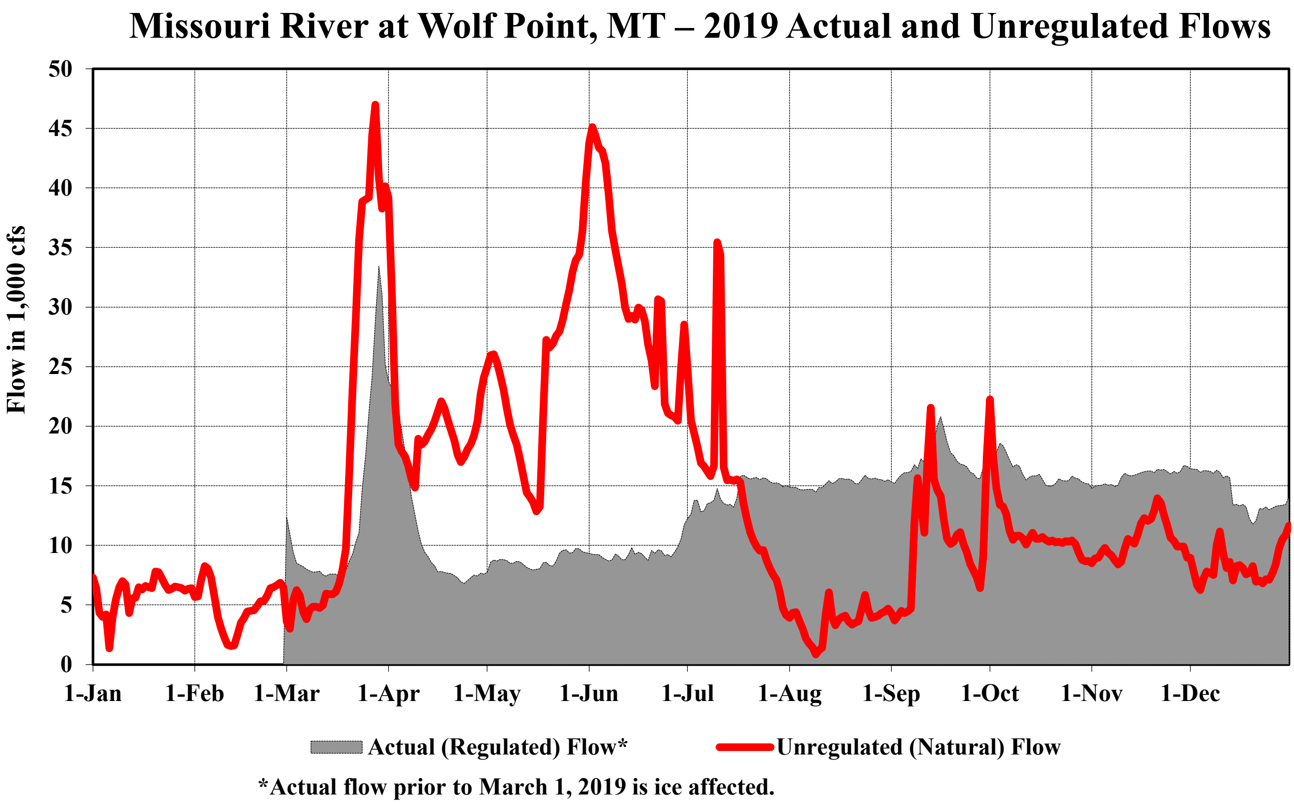


Figure 18. Departure from normal temperature (deg F) for the 2019 3-month periods: January-March, April-June, July-September and October-December. Reformatted from the HPRCC Climate Summary Maps.



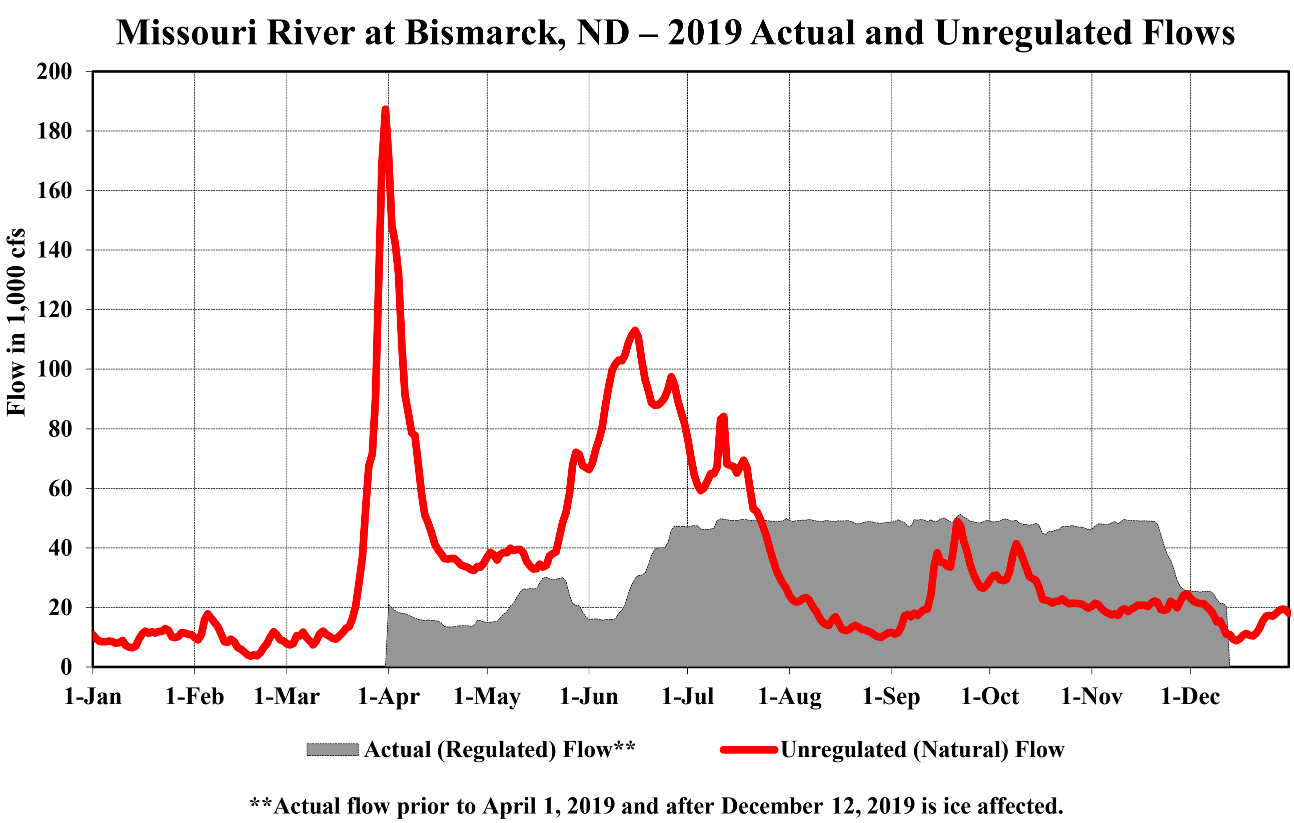
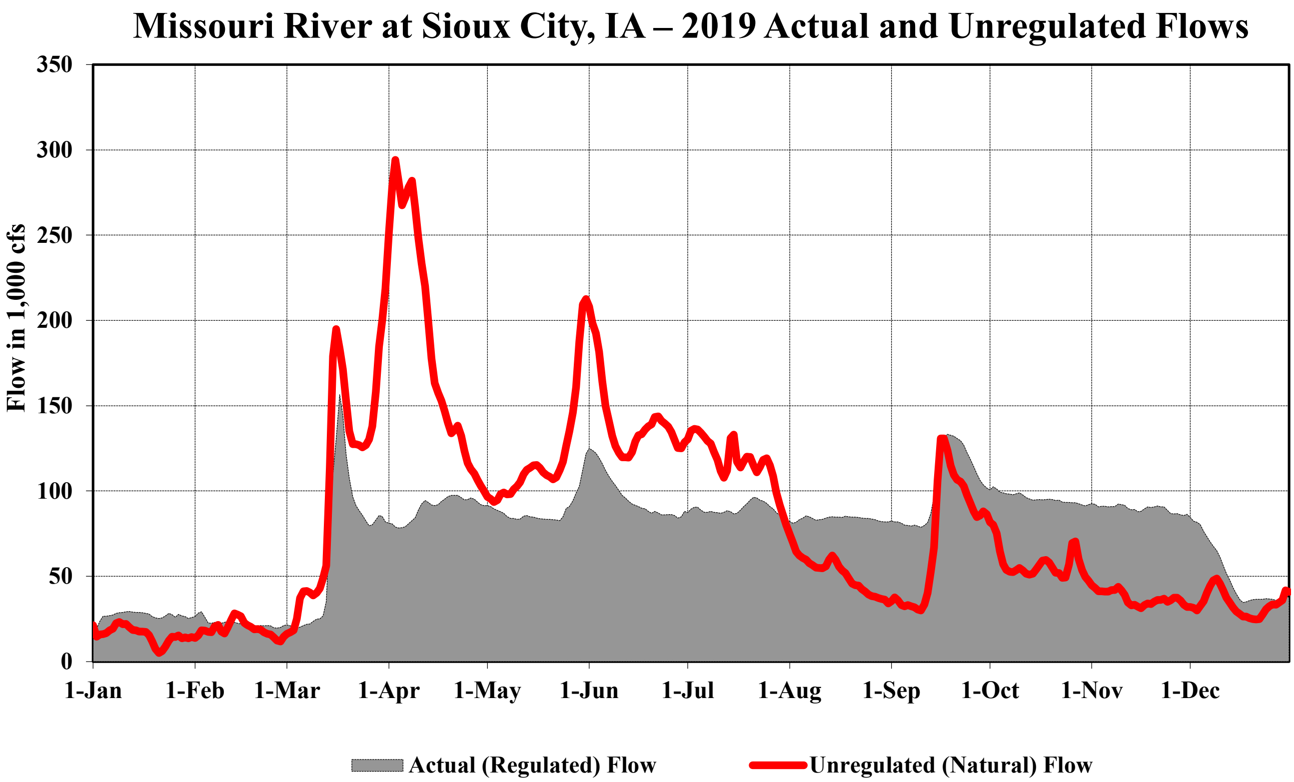


Figure 19A. 2019 actual and unregulated flows – Wolf Point, MT and Bismarck, ND.



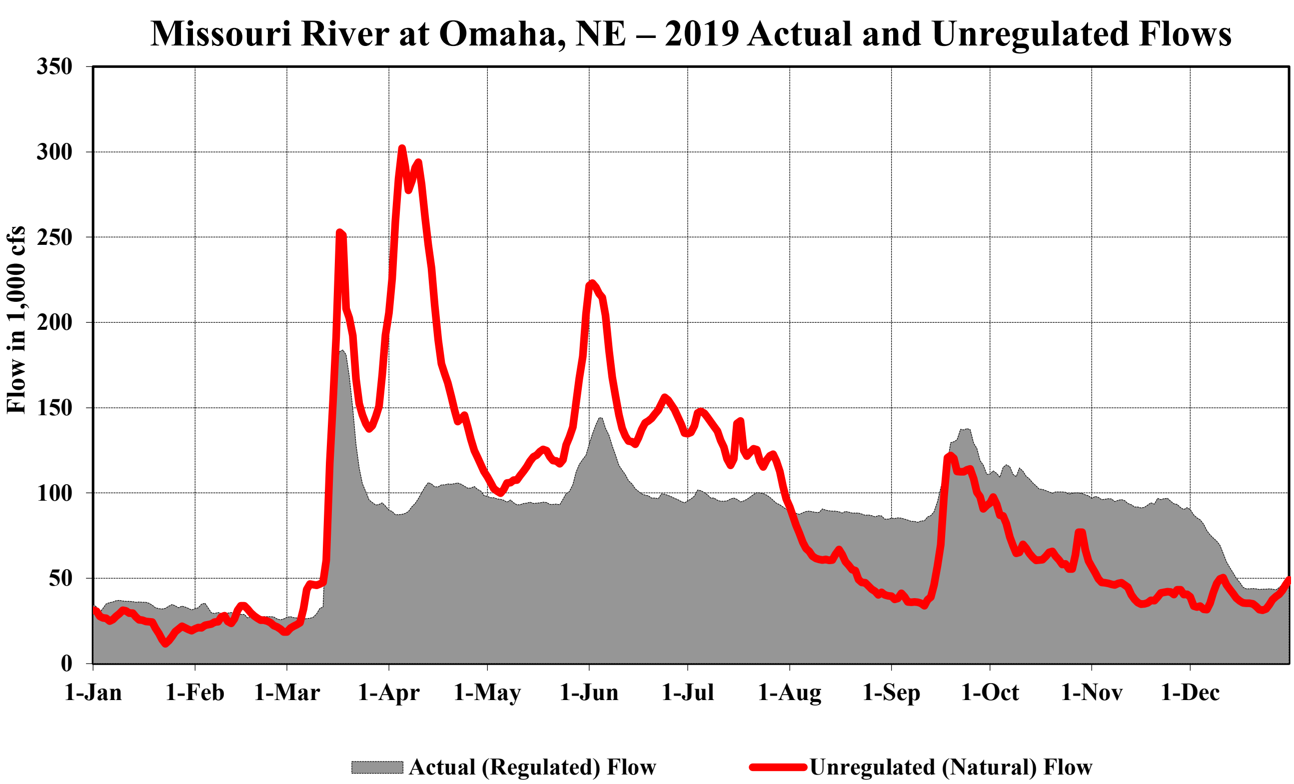
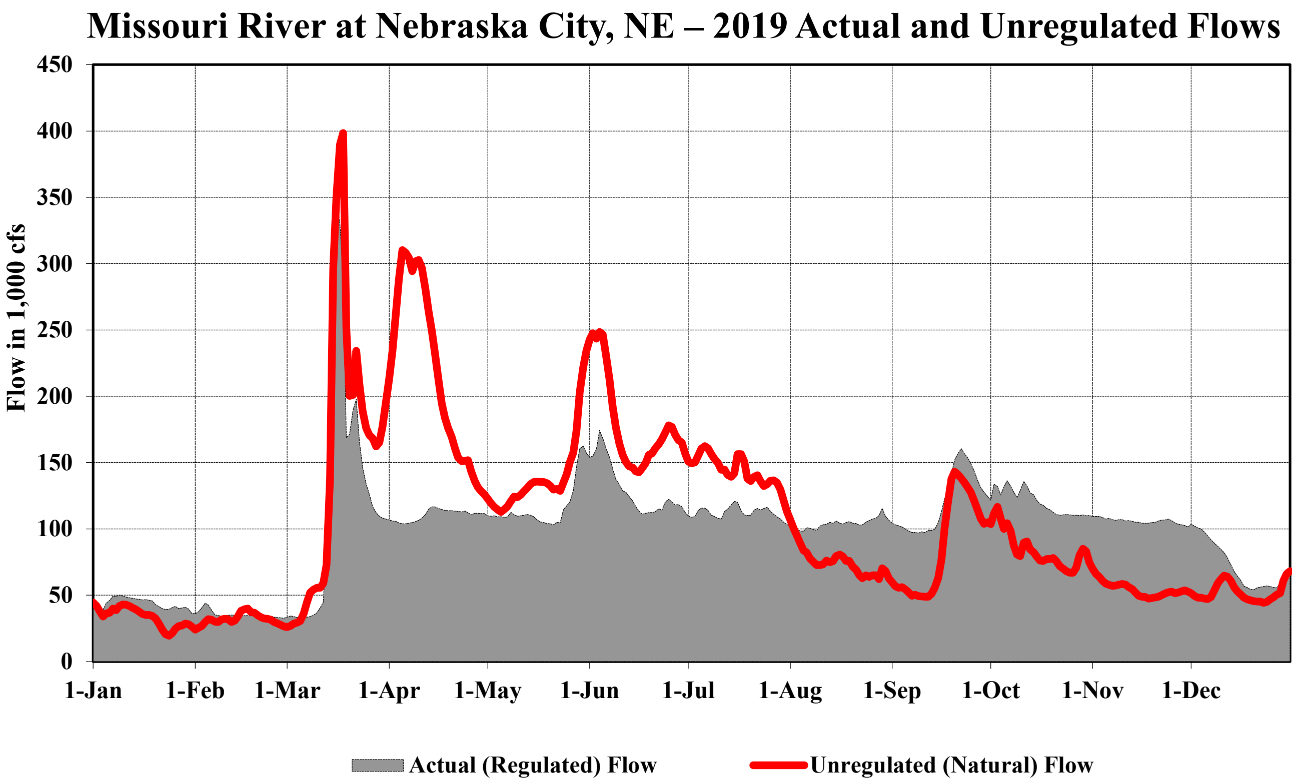


Figure 19B. 2019 actual and unregulated flows – Sioux City, IA and Omaha, NE .



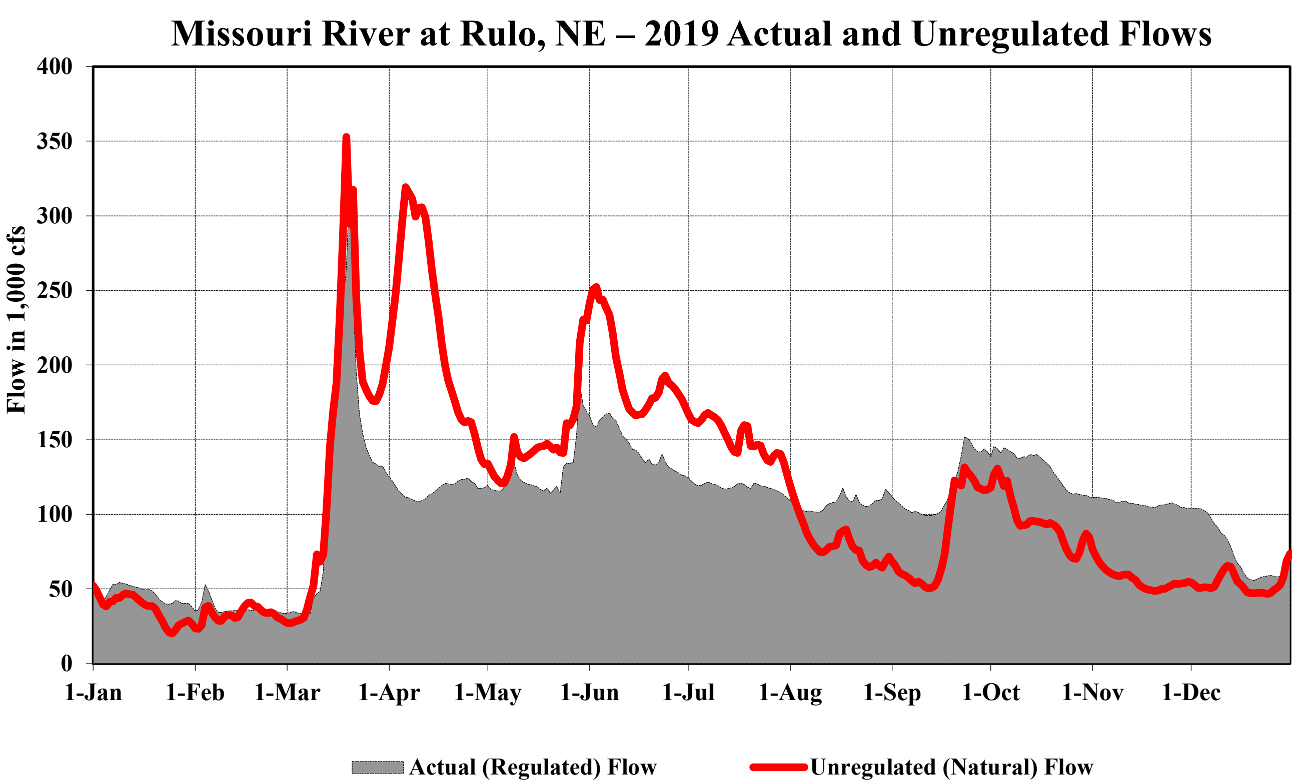
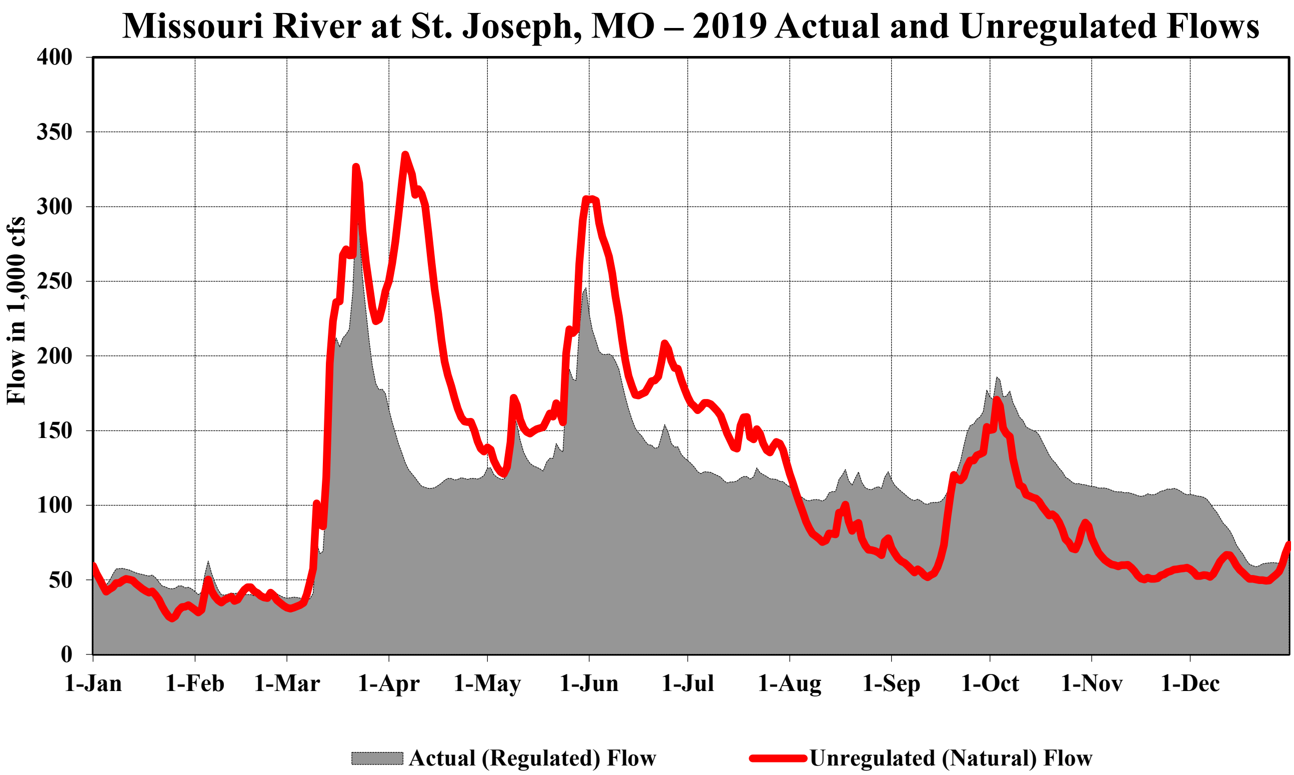


Figure 19C. 2019 actual and unregulated flows – Nebraska City, NE and Rulo, NE.



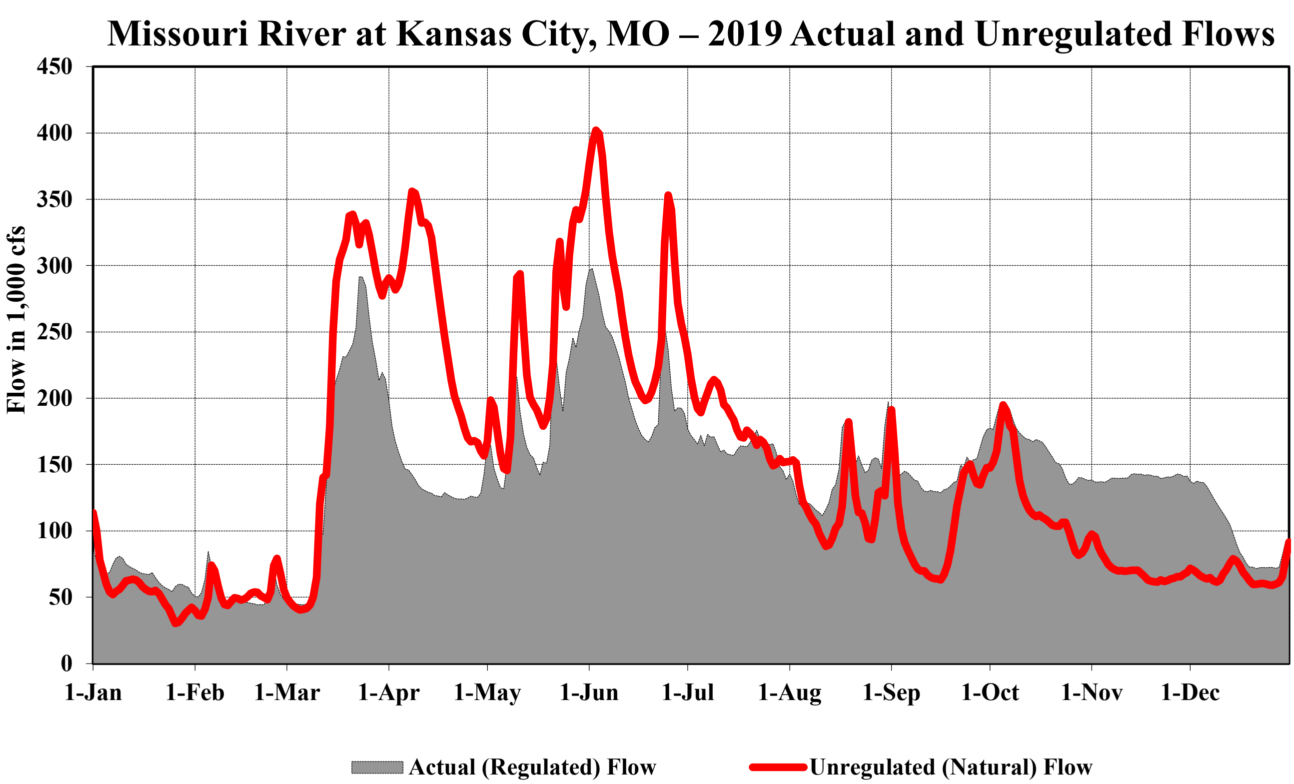
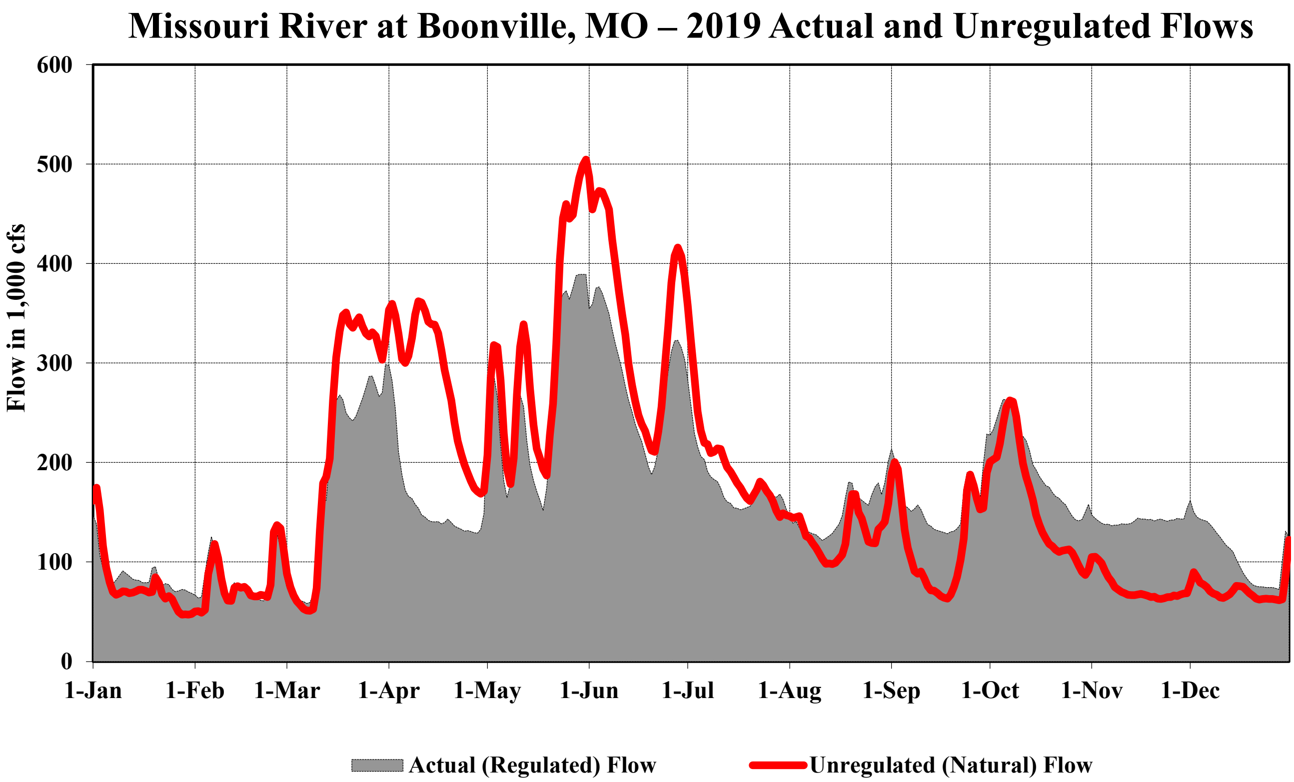


Figure 19D. 2019 actual and unregulated flows – St. Joseph, MO and Kansas City, MO.



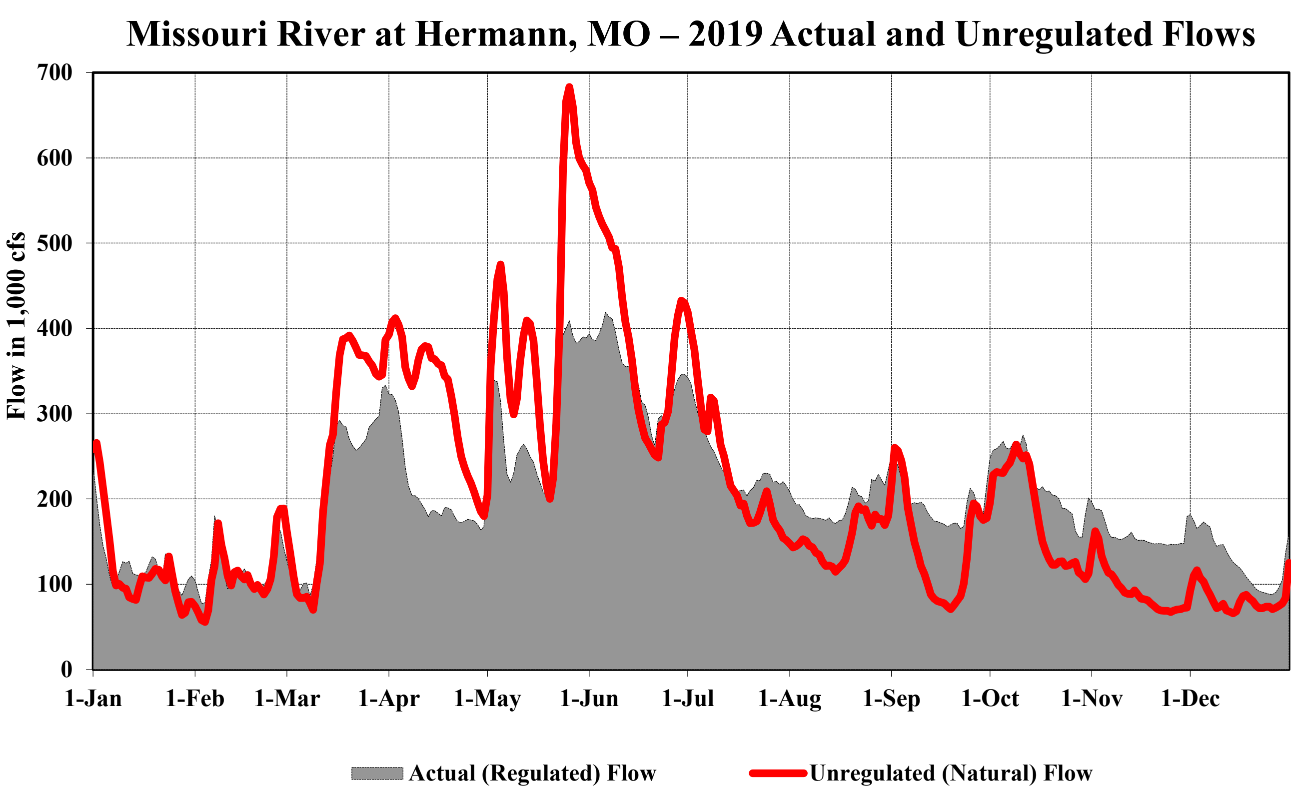


Figure 19E. 2019 actual and unregulated flows – Boonville, MO and Hermann, MO.

The above-normal precipitation continued into the first half of March 2019, most notably in the Dakotas and Nebraska. Two winter storms occurred in quick succession March 9-10 and March 12-15, bringing very heavy snowfall to the Dakotas and heavy rainfall to Nebraska and southeastern South Dakota. The March 9-10 winter storm produced new snowfall ranging from 4 inches in central South Dakota to 6-12 inches in northern South Dakota and southern North Dakota.

From March 12-15, a large, historically deep low pressure system, known as the ‘bomb cyclone’ for its explosive intensification, developed over Colorado and moved northeast across Nebraska and South Dakota. The strong pressure gradients caused a combination of very intense winds, heavy rainfall in the southern and eastern quadrants, and heavy snowfall in the northern and western quandrants of the Missouri River Basin. Total 3-day rainfall accumulations ranged from 2 to over 3 inches over large areas of Nebraska, southeastern South Dakota and western Iowa. The areas of heavy precipitation on March 13-14 are illustrated in ***Figure 20***. The heaviest precipitation occurred in northeastern Nebraska in the upper Elkhorn River basin and the lower Niobrara River basin, and in southeastern South Dakota in the lower James River, Vermillion River and Big Sioux River basins. In addition to the rainfall, heavy snowfall extended from western Nebraska, across central South Dakota into eastern North Dakota. The heaviest snowfall totals ranged from 18 to 24 inches in south central South Dakota, from 12 to 18 inches over central South Dakota, and from 8 to 12 inches in eastern North Dakota.

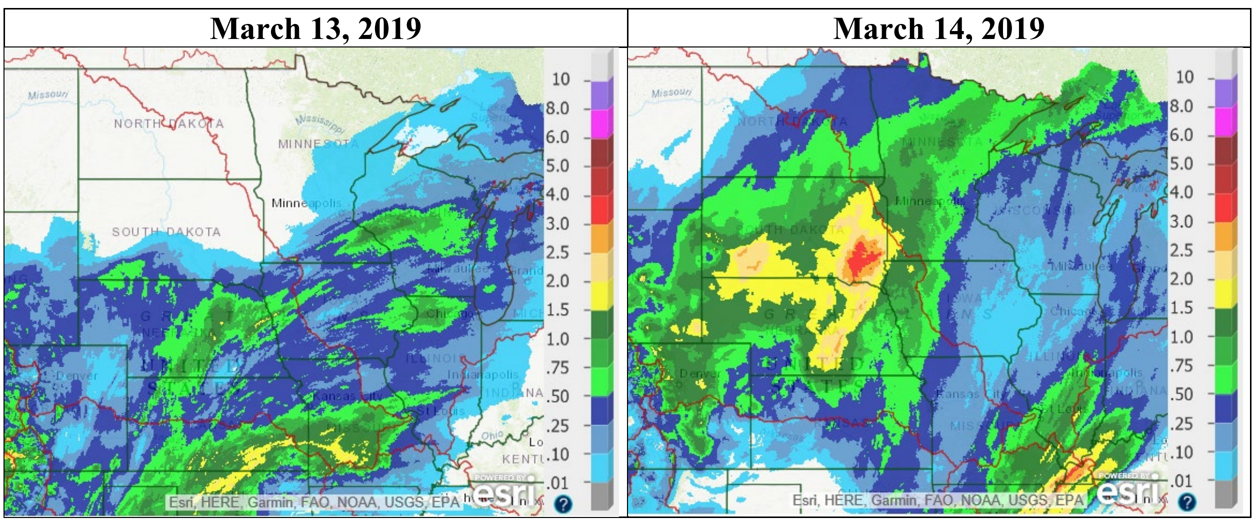


Figure 20. Daily precipitation reported at 6 a.m. on March 13 and 14, 2019. Source: NWS Advanced Hydrologic Prediction Service. https://water.weather.gov/precip/

Total storm precipitation as a result of the ‘bomb cyclone’, depicted as colored contour lines, and SWE on the ground at the time of the storm, depicted as the shaded bands, are shown in ***Figure 21***. The purple rain-snow line indicates that most or all of the precipitation occurred as rainfall south and east of the line, and mostly as snow north and west of the line. Three-day snowmelt in these areas ranged from 1 to over 3 inches, with some areas experiencing 3 to 4 inches of snowmelt (see ***Figure 11***). Overall, this large area received 4 to 7 inches of liquid water from snowmelt and new precipitation as either rain, snow or a rain-snow mixture, most of which ran off into the Missouri River and its tributaries due to the deeply frozen soil.

This rare combination of heavy precipitation and rapidly melting plains snowpack on wet and/or frozen soil conditions resulted in large volumes of water entering the tributaries and eventually the Missouri River. The destructive nature of this storm was further amplified by the thick sheets of ice on the Missouri River tributaries, causing water to dam behind ice jams, which later surged downstream causing record and catastropic flooding. Streamgaging locations on a number of rivers in Nebraska, Iowa and Missouri set stage and/or peak streamflow records (see ***Figure 22***). The most notable stage and flow records occurred on the Niobrara River upstream of Gavins Point Dam, the Elkhorn River and Platte River, and the Missouri River from Nebraska City, NE to Waverly, MO.

c. Spring

The wet pattern continued throughout most of the Missouri River Basin during the April-June period particularly in central Montana and Wyoming, South Dakota, Kansas and Missouri. Month-by-month precipitation accumulations as a percent of normal are shown in ***Figure 17***. April precipitation was above normal in southern Montana, western Wyoming and South Dakota. It was less than 50 percent of normal in southern Nebraska, western Iowa and northern Kansas. May was the wettest month of the 3-month period, and the wettest May on record in 125 years of record-keeping in the states of Nebraska, Kansas and Missouri. South Dakota experienced its fifth wettest May and Iowa experienced its fourth wettest May. June 2019 precipitation was much drier than May and was slightly above normal in southern Nebraska, Kansas and Missouri, and mostly below normal in much of the upper Basin.

Above-normal precipitation during April was focused primarily in southern Montana, western and central Wyoming, and South Dakota. Nearly two times the normal amount of precipitation occurred in these areas in April. For example, Lake Yellowstone, WY received 3.5 inches of precipitation in April, 1.4 inches more than normal. In South Dakota, both Yankton and Sioux Falls received about 5.0 inches in April, 2.0 inches more than normal. As a result of this additional precipitation, high streamflow, and the remaining plains snowmelt, April runoff was 7.8 MAF, 266 percent of average, and particularly high in the Fort Randall, Gavins Point and Sioux City reaches.

May precipitation had as much impact on upper Basin runoff as April precipitation, and it had more impact in the lower Basin on tributary streamflow and runoff. May precipitation was greater than 150 percent of normal over much of Wyoming, South Dakota and Nebraska, and greater than 200 percent of normal in portions of Wyoming, south-central South Dakota, and most of Kansas and Missouri. Rainfall occurred frequently throughout May, with periods of significant rainfall occurring May 17-18 in Montana, North Dakota and South Dakota; May 21-22 in South Dakota, Nebraska, Kansas and Missouri; and May 27-29 in Montana, northwestern Wyoming, South Dakota, Nebraska and northwestern Missouri. As a result of the heavy rainfall, May upper Basin runoff was 8.8 MAF, 262 percent of average, and reached record high volumes in the Oahe, Gavins Point and Sioux City reaches.

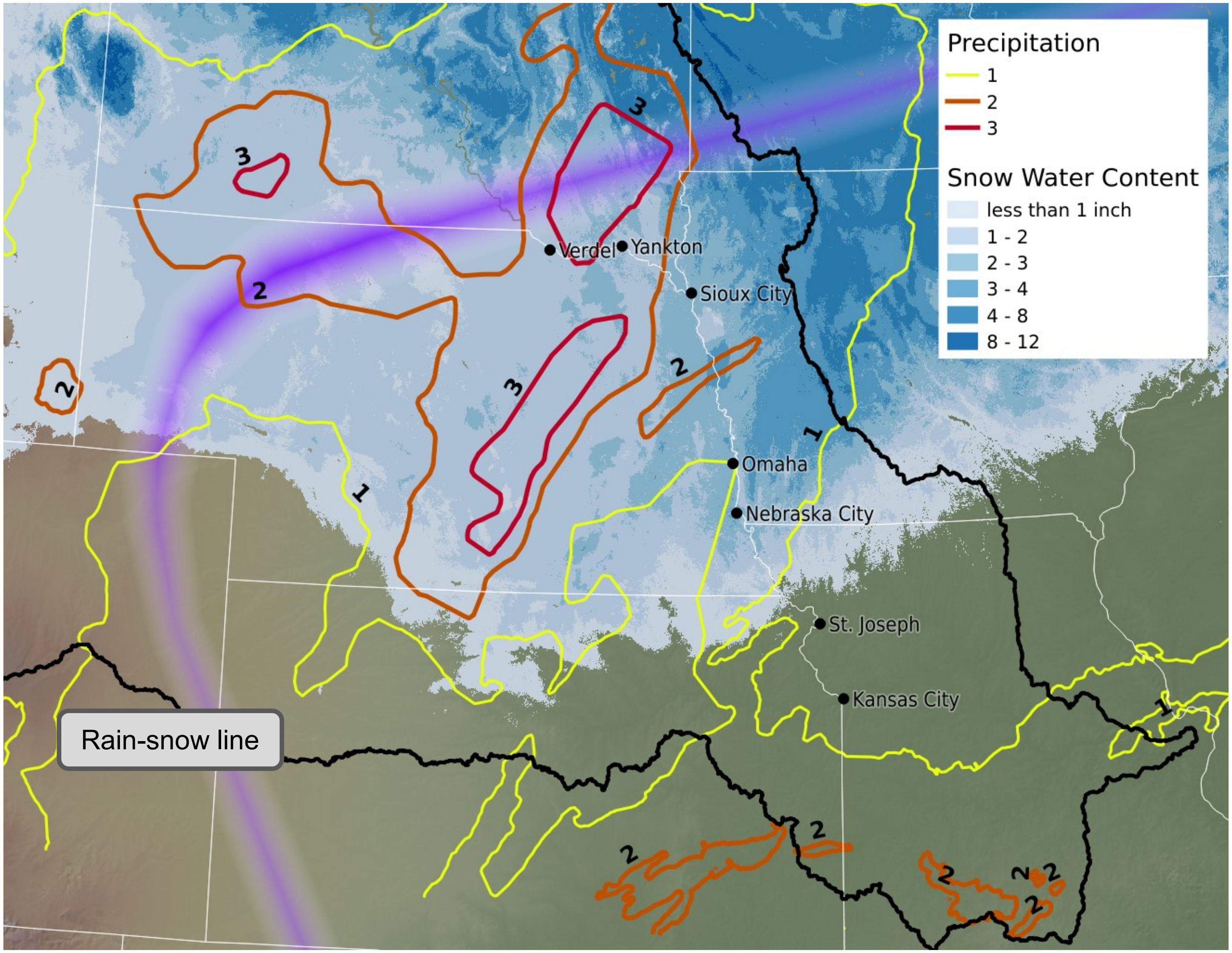
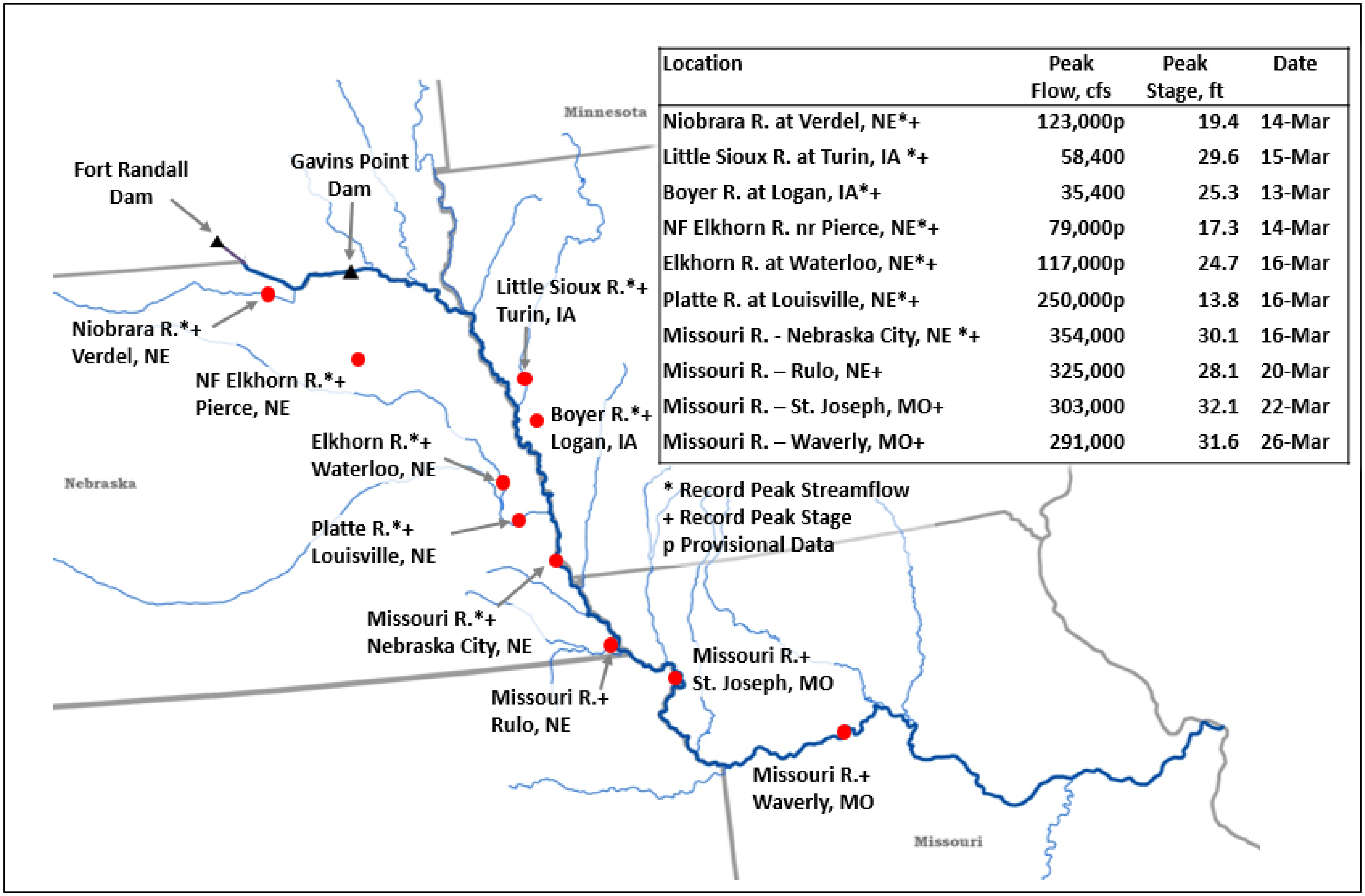


Figure 21. Total storm precipitation for March 12-15, 2019. Graphic used with permission from the NWS MBRFC.



Location	Peak Flow, cfs	Peak Stage, ft	Date
Niobrara R. at Verdel, NE*+	123,000p	19.4	14-Mar
Little Sioux R. at Turin, IA *+	58,400	29.6	15-Mar
Boyer R. at Logan, IA*+	35,400	25.3	13-Mar
NF Elkhorn R. nr Pierce, NE*+	79,000p	17.3	14-Mar
Elkhorn R. at Waterloo, NE*+	117,000p	24.7	16-Mar
Platte R. at Louisville, NE*+	250,000p	13.8	16-Mar
Missouri R. - Nebraska City, NE *+	354,000	30.1	16-Mar
Missouri R. – Rulo, NE+	325,000	28.1	20-Mar
Missouri R. – St. Joseph, MO+	303,000	32.1	22-Mar
Missouri R. – Waverly, MO+	291,000	31.6	26-Mar

Figure 22. Record peak stages and streamflow in the lower Missouri River Basin caused by the March 12-15, 2019 rainfall and snowmelt event. All data is USGS data except Missouri River peak flows, which is Corps data.

May precipitation in northern and central Wyoming ranged from 4 to 6 inches. Riverton and Lander, both in the Wind River Basin, received 4.2 inches and 5.5 inches, respectively, which is nearly two times their normal May precipitation. Buffalo, located in the Powder River basin, received 6.0 inches, more than 3.5 inches above normal. Sheridan received 6.3 inches, 4.0 inches above normal. Western and southern South Dakota received monthly rainfall totals ranging from 5 to 8 inches with heaviest areas approaching 8 to 11 inches in the Fort Randall reach. The Fort Pierre/Pierre, SD area received 7.5 inches, while the towns of Murdo and Kennebec, located in the Oahe to Fort Randall reach, received 11 inches and 9.5 inches, respectively. The normal May rainfall in central South Dakota is approximately 3 inches. Farther east, Yankton, Sioux Falls and Sioux City, IA received 6 to 7 inches of rainfall.

During May, much of central and eastern Nebraska received 5 to 8 inches of rainfall with the heaviest rainfall ranging from 8 to 9 inches in central Nebraska and from 8 to over 12 inches in southeastern Nebraska and southwestern Iowa. Reports in the Niobrara River basin of northern Nebraska, which drains into the Gavins Point reservoir (Lewis and Clark Lake), include 7.4 inches in Valentine and 8.3 inches in Ainsworth. In eastern Nebraska rainfall amounts include 7.7 inches in Omaha and 13.5 inches in Falls City; while in southwestern Iowa, amounts include 11.3 inches in Red Oak and 12.1 inches in Shenandoah, more than two times the normal May amount.

In Kansas, the statewide average rainfall during May 2019 was 10.3 inches, almost 250 percent of normal. Rainfall totals ranged from 10 to over 13 inches in northeastern Kansas, and 13 to 16 inches in eastern Kansas within the Missouri River Basin. Some heavy monthly totals in the lower Kansas River basin include 10.7 inches in Abilene, 12.6 inches in Clay Center, 14.1 inches in Manhattan, 10.0 inches in Topeka, 11.1 inches at Clinton Lake, and 10.6 inches at Perry Lake. Pomona Lake, which is in eastern Kansas and in the Osage River basin, received 14.3 inches. Heavy rainfall ranging from 10 to over 16 inches also occurred in north-central Missouri and southwestern Missouri, including 12.8 inches in Kansas City, 12.3 inches in Smithville, 14.1 inches in Chillicothe, and 16.0 inches in Kirksville. High local streamflow from the heavy rainfall resulted in the annual stage and flow crests on the Missouri River from Kansas City to Hermann from late May to early June (see ***Figure 19D*** and ***Figure 19E***).

June 2019 precipitation ranged from above normal in north-central Montana to below normal in western and southern Montana, Wyoming, North Dakota, South Dakota and western Iowa (see ***Figure 17***). Rainfall in north-central and northeastern Montana generally ranged from 2.5 to 4 inches; normal June rainfall for the area is about 2.5 inches. Plentywood, in northeastern Montana, received 5.9 inches, more than 3 inches above normal. Wolf Point received 4.5 inches, about 1.5 inches above normal. The greatest total of 9.9 inches, almost three times the normal amount, was reported at Zortman near Landusky, MT. Runoff from the June rainfall coincided with runoff from the mountain snowmelt in the Fort Peck and Garrison reaches, resulting in above-average runoff in the Fort Peck and Garrison reaches in June. Precipitation was quite variable in the lower Basin and there were no significant rainfall events influencing runoff and streamflow.

d. Summer

The July-September period was much wetter than normal in the upper Basin and in much of Nebraska, Kansas and western Missouri. Month-by-month precipitation totals as a percent of normal are shown in ***Figure 17***. During the 3-month period, North Dakota and South Dakota experienced their wettest July-September period in 125 years of record-keeping. As a result of continued heavy precipitation, combined with the remaining mountain snowmelt in the Fort Peck and Garrison reaches, the monthly runoff summation for the upper Basin was no less than two times the long-term average amount in July and August, while in September the runoff summation was more than four times average.

During July the storm pattern occurred repeatedly from southwestern Montana into northwestern Iowa, leading to more than 150 percent of normal precipitation in southern Montana, northern Wyoming, southern North Dakota, South Dakota, northern and central Nebraska, southwestern Minnesota and northwestern Iowa. Numerous locations in south-central and southeastern Montana received between 4 and 6 inches of rainfall. Most notably, Yellowtail Dam received 4.0 inches, 2.6 inches more than normal. Broadus, in the Powder River basin, received 6.3 inches, almost four times the normal July amount. The Rapid City, SD area received up to 6.4 inches, more than three times the normal amount. Lead, in the northern Black Hills, received 8.8 inches, 6 inches more than the 2.8-inch normal. Much of southeastern and eastern South Dakota received 6.5 to over 8 inches of precipitation, including 8.3 inches in Winner, 7.0 inches at Gregory, 7.9 inches in Chamberlain, 9.5 inches in Academy, and 6.8 inches at Sioux Falls.

Heavy August precipitation, shown in ***Figure 17***, covered a large area of the Missouri River Basin, and added about 2.5 times the average August runoff to the upper Basin during what is typically a drier precipitation period. While not as heavy as the July precipitation, August precipitation was greater than 150 percent of normal over much of eastern Montana, western North Dakota, northeastern Wyoming, South Dakota, Nebraska, Kansas and Missouri. Precipitation departures typically ranged from 1 to 2 inches in Montana and North Dakota and 1.5 to over 3 inches in central and eastern South Dakota.

Over a large portion of western and central Nebraska, August rainfall totals were more than 150 percent of normal, with departures ranging from 1.5 to 3 inches over this area, and ranging from 3 to 6 inches in central Nebraska. Locations and amounts of the heaviest August rainfall include 11.9 inches in Grand Island, 9.8 inches in Ord, and 13.8 inches in St. Paul. August rainfall caused severe localized flooding in these areas and also resulted in high streamflow on the Platte River. High streamflows occurred on the Republican and Big Blue rivers, which both drain into lower Kansas River basin Corps reservoirs.

August precipitation was also very heavy in eastern Kansas, ranging from 8 to over 14 inches in the eastern third of the state. Precipitation was particularly heavy in the lower Kansas River basin and the upper Osage River basin. Both basins had locations that recorded several 16-inch and greater August totals. Topeka recorded 12.0 inches, while Lawrence recorded 11.4 inches. Clinton Lake recorded a 1-day total of 8.2 inches on August 1, and an astonishing 20.5 inches in August, nearly five times the normal amount and over half of its normal annual precipitation.

Clinton Lake would eventually record 59.8 inches of rain in 2019, exceeding its previous annual maximum total of 54.4 inches, set in 1993. Ottawa, KS recorded 18.3 inches in August, almost half its normal annual precipitation. The Ottawa annual precipitation total reached 64.6 inches in 2019, exceeding the previous maximum annual precipitation of 58.4 inches, set in 1915.

During September, the upper Basin and western Iowa received more than two times normal precipitation in most areas, while much of Nebraska, Kansas and Missouri received below-normal precipitation. September rainfall in the upper Basin significantly increased streamflow in the upper Basin. The result was September runoff of 5.0 MAF, more than four times the average amount, and the record wettest September runoff summation by almost two times the previous September high. The record high September runoff led to a significant mid-September increase in System releases in order to evacuate 2019 stored floodwater. The areas of heavy rainfall on very wet, nearly saturated soil occurred primarily in three areas of the Missouri Basin: northeastern Montana to central North Dakota, north-central Nebraska to eastern South Dakota, and western Iowa to northern Missouri.

Heavy September rainfall occurred in the Garrison reservoir reach of northeastern Montana to central North Dakota and the upper James River basin above Jamestown and Pipestem reservoirs. Total September rainfall generally ranged from 5 to over 9 inches; however, some localized areas received more. Heavy rain occurred in northeastern Montana from September 7-12 including 4.5 inches at Glendive and 5.9 inches at Sidney. Additional rainfall occurred September 18 and 29 bringing monthly totals to 8.5 and 10.3 inches at Glendive and Sidney, respectively, compared to normal September precipitation of about 1.3 inches. In North Dakota, Williston and Underwood, which are located at opposite ends of Lake Sakakawea, received monthly totals of 8.1 inches, much of which occurred September 7-12. Turtle Lake, located near Garrison Dam, received 9.7 inches in September. In the upper James River basin, Carrington received 8.7 inches and Jamestown received 5.6 inches, more than twice their September normals of 2.3 inches.

In north-central Nebraska and eastern South Dakota, heavy rainfall due to slow-moving thunderstorms occurred repeatedly on September 11-12 (see ***Figure 23***). Ainsworth, NE, located in the upper Niobrara River basin above Gavins Point Dam, received 8 inches from September 11-12 and a September total of 10.0 inches. From southeastern South Dakota to southwestern Minnesota, 3 to 8 inches occurred September 11-12, and a band of extremely heavy rainfall ranging from 6 to 10 inches occurred from Mitchell to Madison, SD to Slayton, MN. The most intense areas of greater than 10 inches, indicated by the darkest shade of red in ***Figure 23***, occurred along I-90 east of Mitchell, SD and north of Worthington, MN. The intense rainfall and runoff caused a number of tributaries to exceed their record flood stages, including the James River at Scotland and Yankton, the Big Sioux River at Dells Rapids, the East Fork Vermillion River at Parker, and Split Rock Creek at Corson. September runoff in the Sioux City reach was 1.9 MAF, more than 15 times the average September runoff, and a new record September runoff volume that was two times the previous record.

Similar heavy amounts of rainfall occurred in western Iowa in September including 12.6 inches in Little Sioux, 6.7 inches in Logan, 8.0 inches in Clarinda, and 8.4 inches in Shenandoah, all of which were two to three times their normal September rainfall amount.

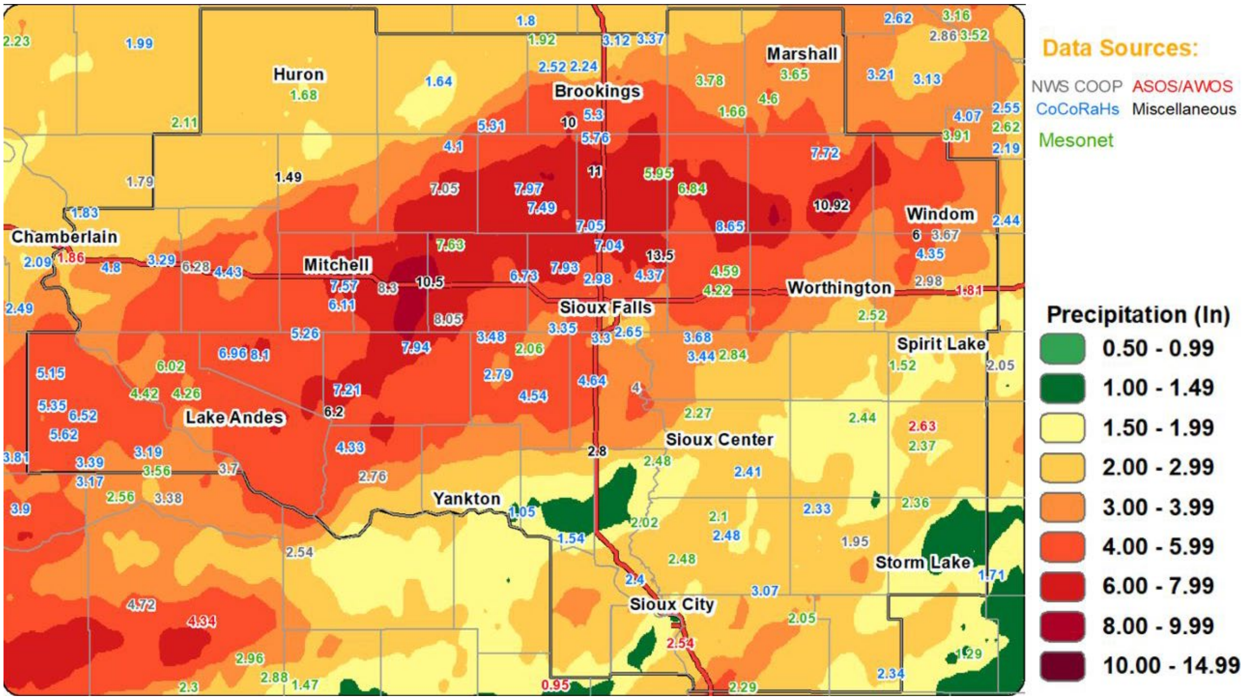


Figure 23. 48-hour rainfall totals for September 11-12, 2019 in Southeastern South Dakota and Southwestern Minnesota. Graphic courtesy of the NWS Sioux Falls.

e. Fall

October-December precipitation varied from well-above normal to well-below normal throughout the Missouri River Basin. Areas of above-normal precipitation included north-central Montana, central and eastern North Dakota, South Dakota, eastern Nebraska and Iowa. Areas of below-normal precipitation included the headwaters of the upper Missouri River and upper Yellowstone River, western Nebraska, eastern Kansas and Missouri. Temperatures were generally 2 to 4 deg F below normal in the upper Basin and 0 to 2 deg F below normal in the lower Basin.

October precipitation was greater than 150 percent of normal in northern South Dakota and much of North Dakota due in part to a large snowstorm that accumulated several feet of snow in areas of these states from October 10-13. In North Dakota, Bismarck received 17.1 inches, while Harvey near the upper James River basin received 30 inches. Widespread amounts ranged from 12 to 18 inches across south-central North Dakota, while 18 to 24 inches fell in the upper James River basin. A second potent storm produced heavy rainfall October 20-21 in north-central South Dakota and south-central North Dakota. Radar-estimated rainfall ranged from 2 to 3 inches in the Cannonball and Grand River basins, which contributed to significant inflows into the Oahe reservoir. Two-day rainfall totals include 2.1 inches at Mobridge, SD, 1.5 inches at Bismarck, ND, and about 1 inch at Jamestown, ND. For the month of October, Bismarck, ND received 3.4 inches of precipitation, 2.1 inches more than normal, and 17 inches of snowfall, 14.9 inches more than the October normal. Some other notable rainfall totals were 6.4 inches in Worthington, MN (4.4 inches above normal); 4.1 inches in Vermillion, SD (1.9 inches above normal); and 5.6 inches in Omaha, NE (3.5 inches above normal).

November precipitation varied from more than two times normal (see ***Figure 17***) in areas of central Nebraska, northern and central Montana, western South Dakota, central North Dakota and Wyoming to less than 50 percent of normal in eastern Montana, North Dakota and Kansas. Precipitation in Great Falls, MT, a location representative of the wet snowy conditions in central Montana, received 1.3 inches of precipitation, twice the normal amount, and around 24 inches of snow, which is three times the normal November amount. Conrad, MT received 2.7 inches of liquid precipitation, over five times the normal November precipitation and 35 inches of snow, which is seven times the normal November snowfall.

December precipitation was generally below normal in Montana and northern Wyoming, and above normal in the Dakotas and Nebraska. Precipitation was more than two times normal over large areas of Nebraska, South Dakota and eastern North Dakota. This precipitation was caused primarily by a large winter storm that traversed these areas from December 27-30. The storm produced a mix of rain, freezing rain, and snow as it developed in Nebraska, before mostly producing snow as it moved into South Dakota and southern North Dakota. Snowfall totals generally ranged from 6 to 12 inches; however some concentrated areas of northern South Dakota and southeastern North Dakota received 12 to 24 inches. Since temperatures were well-above normal throughout the upper Basin, plains snowpack formation was limited to areas of eastern North Dakota and northeastern South Dakota.

f. Summary

In 2019 the Missouri River Basin received record or near-record precipitation accompanied by below-normal temperatures. In addition, the upper Basin and portions of the lower Basin received heavy snowfall and experienced very low temperatures during February and March, establishing moisture-rich conditions that caused record flooding in March 2019, followed by major flooding along the Missouri River throughout the spring and summer 2019. Nearly all regions of the Missouri River Basin experienced very heavy, intense precipitation events that caused localized flooding and record high tributary flows and stages, particularly in March and September.

6. 2019 Calendar Year Runoff

The 2019 unregulated runoff volume for the upper Basin above Sioux City, IA totaled 60.9 million acre-feet (MAF), 239 percent of average, based on the historical period of 1898-2018, as shown in ***Table 4*** and ***Figure 24***. The 2019 upper Basin runoff is the second highest runoff in 122 years of record-keeping, exceeded only in 2011 (61.0 MAF). ***Table 4*** lists the runoff for the upper Basin by month and reach and compares the 2019 monthly and calendar year totals to the 1898-2018 historical period average. Monthly and calendar year totals are the adjusted compilation of runoff into the System. This forecast forms a basis for intra-system balancing of storage accumulated in the System and is updated by MRBWM on the first of each month to forecast the runoff for the remainder of the year. The monthly accumulation of actual runoff is shown under the "Accumulated Summation above Sioux City" column.

Runoff was above average in all six reaches in the upper Basin, as outlined in ***Table 4.*** During March, April and May, the upper Basin received 27.5 MAF, more than an average year's runoff. The 2019 runoff in the lower four reaches of 34.8 MAF was nearly five times average (7.4 MAF) and was the highest recorded runoff in each of the lower four reaches. Most significantly, the runoff in the Gavins Point to Sioux City reach was 14.8 MAF, more than six times average (2.3 MAF) and more than 4 MAF greater than the previous record high of 10.6 MAF, set in 2010.

Runoff in the lower Basin, from Sioux City, IA to Hermann, MO, totaled 91.6 MAF, 218 percent of average (see ***Table 5***). Runoff in all three reaches in the lower Basin was much-above average. The lower Basin runoff was third highest on record (1958-2019), exceeded only in 1973 (94.1 MAF) and 1993 (116.4 MAF).

Table 4
Missouri River Basin
2019 Runoff above Sioux City, IA

Values in 1000 Acre Feet

Reach Above	Fort Peck	Garrison	Oahe	Fort Randall	Gavins Point	Sioux City	Summation above Gavins Point	Summation above Sioux City	Accumulated Summation above Sioux City
	(Actual)								
JAN 2019	326	204	2	-13	139	254	658	912	912
AVERAGE*	312	264	12	32	101	56	721	776	776
DEPARTURE	14	-60	-10	-45	38	198	-63	136	136
% OF AVE	104%	77%	16%	-41%	138%	457%	91%	117%	117%
FEB 2019	264	246	134	189	125	177	958	1,135	2,047
AVERAGE*	364	362	99	58	134	106	1,018	1,123	1,900
DEPARTURE	-100	-116	35	131	-9	71	-60	12	147
% OF AVE	72%	68%	135%	327%	93%	168%	94%	101%	108%
MAR 2019	1,172	2,277	2,276	1,574	1,207	2,329	8,506	10,835	12,882
AVERAGE*	597	1,002	578	212	210	328	2,599	2,927	4,826
DEPARTURE	575	1,275	1,698	1,362	997	2,001	5,907	7,908	8,056
% OF AVE	196%	227%	394%	743%	574%	710%	327%	370%	267%
APR 2019	1,094	1,749	1,553	656	482	2,302	5,534	7,836	20,718
AVERAGE*	646	1,083	501	145	180	386	2,555	2,941	7,767
DEPARTURE	448	666	1,052	511	302	1,916	2,979	4,895	12,951
% OF AVE	169%	161%	310%	451%	268%	597%	217%	266%	267%
MAY 2019	1,488	1,580	1,650	1,402	672	2,013	6,792	8,805	29,523
AVERAGE*	1,089	1,283	324	149	187	332	3,032	3,364	11,131
DEPARTURE	399	297	1,326	1,253	485	1,681	3,760	5,441	18,392
% OF AVE	137%	123%	509%	942%	360%	606%	224%	262%	265%
JUN 2019	1,870	3,734	829	270	589	1,384	7,292	8,676	38,199
AVERAGE*	1,636	2,746	446	162	184	334	5,175	5,509	16,639
DEPARTURE	234	988	383	108	405	1,050	2,117	3,167	21,560
% OF AVE	114%	136%	186%	167%	319%	414%	141%	157%	230%
JUL 2019	1,062	2,781	1,048	400	466	1,230	5,757	6,987	45,186
AVERAGE*	828	1,825	193	58	138	254	3,043	3,297	19,937
DEPARTURE	234	956	855	342	328	976	2,714	3,690	25,249
% OF AVE	128%	152%	542%	685%	337%	484%	189%	212%	227%
AUG 2019	457	877	494	491	326	886	2,645	3,531	48,717
AVERAGE*	360	614	82	43	117	155	1,216	1,370	21,307
DEPARTURE	97	263	412	448	209	731	1,429	2,161	27,410
% OF AVE	127%	143%	605%	1139%	280%	573%	218%	258%	229%
SEP 2019	513	1,113	492	481	543	1,886	3,142	5,028	53,745
AVERAGE*	327	449	112	38	111	119	1,037	1,155	22,462
DEPARTURE	186	664	380	443	432	1,767	2,105	3,873	31,283
% OF AVE	157%	248%	440%	1277%	490%	1591%	303%	435%	239%
OCT 2019	506	932	447	-32	316	989	2,169	3,158	56,903
AVERAGE*	380	533	71	3	120	102	1,106	1,208	23,670
DEPARTURE	126	399	376	-35	196	887	1,063	1,950	33,233
% OF AVE	133%	175%	634%	--	263%	973%	196%	261%	240%
NOV 2019	532	417	85	-81	244	653	1,197	1,850	58,753
AVERAGE*	380	390	68	3	119	88	959	1,047	24,717
DEPARTURE	152	27	17	-84	125	565	238	803	34,036
% OF AVE	140%	107%	125%	--	206%	744%	125%	177%	238%
DEC 2019	443	409	239	213	155	659	1,459	2,118	60,871
AVERAGE*	327	254	7	13	101	65	702	768	25,485
DEPARTURE	116	155	232	200	54	594	757	1,350	35,386
% OF AVE	135%	161%	--	1627%	154%	1011%	208%	276%	239%
Calendar Year Totals									
	9,727	16,319	9,249	5,550	5,264	14,762	46,109	60,871	
AVERAGE*	7,247	10,805	2,492	916	1,701	2,323	23,162	25,485	
DEPARTURE	2,480	5,514	6,757	4,634	3,563	12,439	22,947	35,386	
% OF AVE	134%	151%	371%	606%	309%	635%	199%	239%	

*1898-2018

Table 5
2019 CY Runoff Volumes for Selected Reaches (1,000 acre-feet)

Reach	1898-2018 Average Runoff	2019 CY Runoff	% of Average Runoff
Above Fort Peck	7,247	9,727	134
Fort Peck to Garrison	10,805	16,319	151
Garrison to Oahe	2,492	9,249	371
Oahe to Fort Randall	916	5,550	606
Fort Randall to Gavins Point	1,701	5,264	309
Gavins Point to Sioux City	2,323	14,762	635
TOTAL ABOVE SIOUX CITY	**25,485**	**60,871**	**239**
	1958-2018 Average Runoff	**2019 CY Runoff**	**% of Annual Runoff**
Sioux City, IA to Nebraska City, NE*	7,907	18,320	232
Nebraska City, NE to Kansas City, MO*	11,306	29,944	265
Kansas City, MO to Hermann, MO*	22,780	43,350	190
TOTAL BELOW SIOUX CITY*	**41,993**	**91,614**	**218**

* *Runoff in the reaches from Sioux City, IA to Hermann, MO is not adjusted to 1949 depletion levels. Annual monthly averages are taken from the USGS Water Data Reports for the period 1958-2018.*

Total runoff in the Missouri River Basin was 152.5 MAF, more than two times average and 0.1 MAF less than the highest runoff of record, 152.6 MAF in 1993. ***Figure 25*** shows the total basin runoff since 1958, when the Missouri River at Hermann streamgaging station was established. ***Table 6*** shows the monthly ranking with one being the highest or record for each month of 2019 for the six upper Basin reaches, as well as the summation above Sioux City. Many reaches set new monthly records. See ***Plate 3*** for a listing of locations throughout the Missouri River Basin that experienced peak stages and/or flows in 2019.

Table 6
Ranking of Monthly and Calendar Year Runoff Volumes by Reach Compared to the 1898-2019 Historical Record

Month	Fort Peck	Garrison	Oahe	Fort Randall	Gavins Point	Sioux City	Summation ab Sioux City
January	46	86	67	87	19	5	**32**
February	99	91	28	7	50	21	**48**
March	6	2	2	1	1	1	**1**
April	10	17	9	2	1	2	**3**
May	23	29	1	2	1	1	**2**
June	38	17	21	21	1	3	**8**
July	33	18	2	2	2	4	**4**
August	29	24	3	1	1	2	**2**
September	11	1	8	1	1	1	**1**
October	22	6	5	87	1	1	**2**
November	13	49	39	112	3	1	**3**
December	9	11	6	1	13	1	**1**
Calendar Year	**18**	**7**	**1**	**1**	**1**	**1**	**2**

Figure 22 illustrates the streamgaging locations in the Missouri River Basin that observed record stages and flows during the March 2019 event. See Section II.B.5 for more details.

Figure 26 illustrates the monthly variation of the runoff summation above Sioux City, IA compared to the long-term average variation of runoff based on the 1898-2018 historic period. Runoff in 2019 was above average during every month. January and February was slightly above average at 117 percent and 101 percent, respectively. Runoff during the next ten months was significantly above average. As noted in Section II.B, above-normal precipitation throughout the Missouri River Basin fell on heavily saturated soils during March-December and resulted in near-record runoff during 2019.

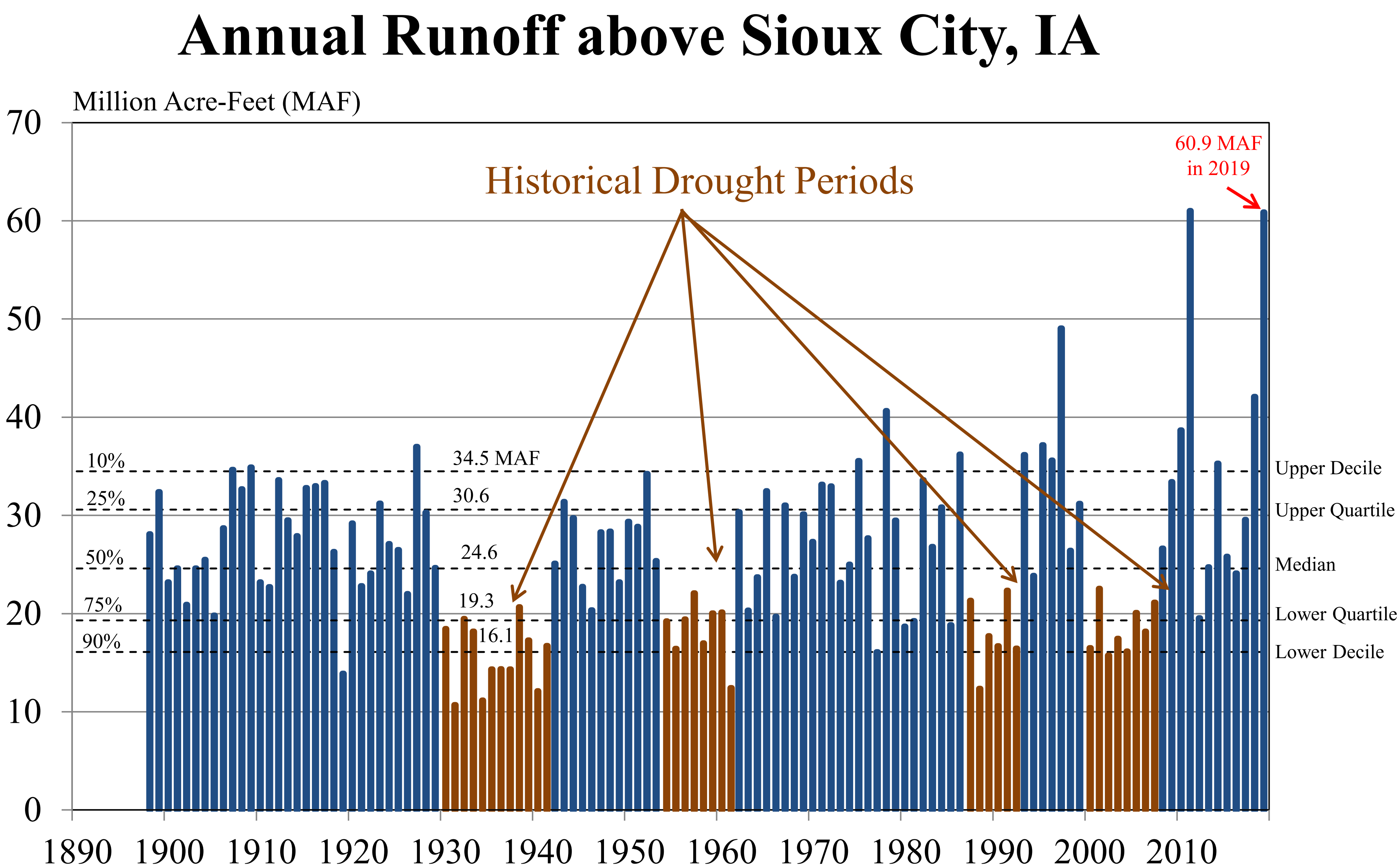


Figure 24. Missouri River Basin annual runoff above Sioux City, IA.

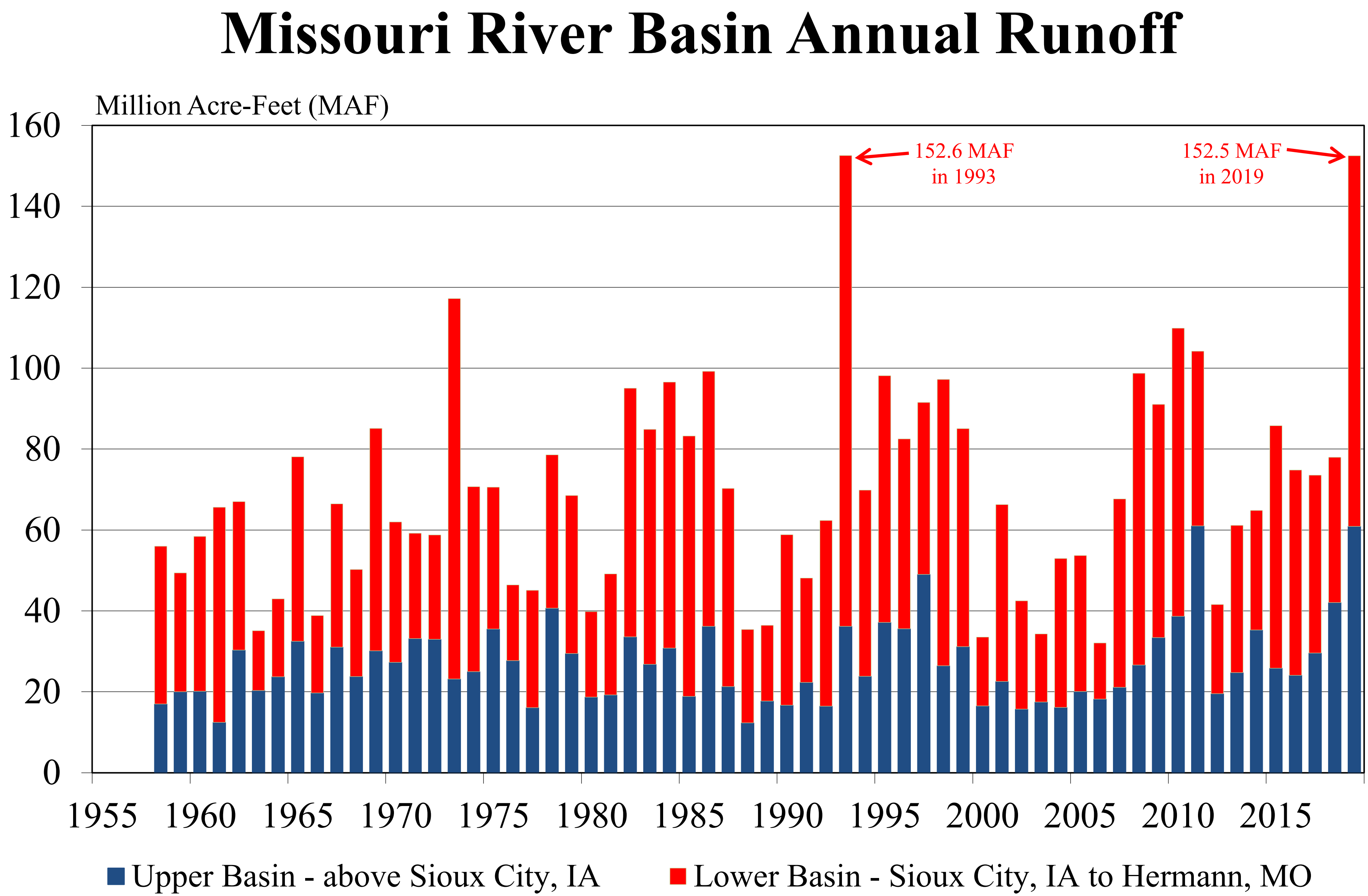


Figure 25. Missouri River Basin annual runoff above Hermann, MO.

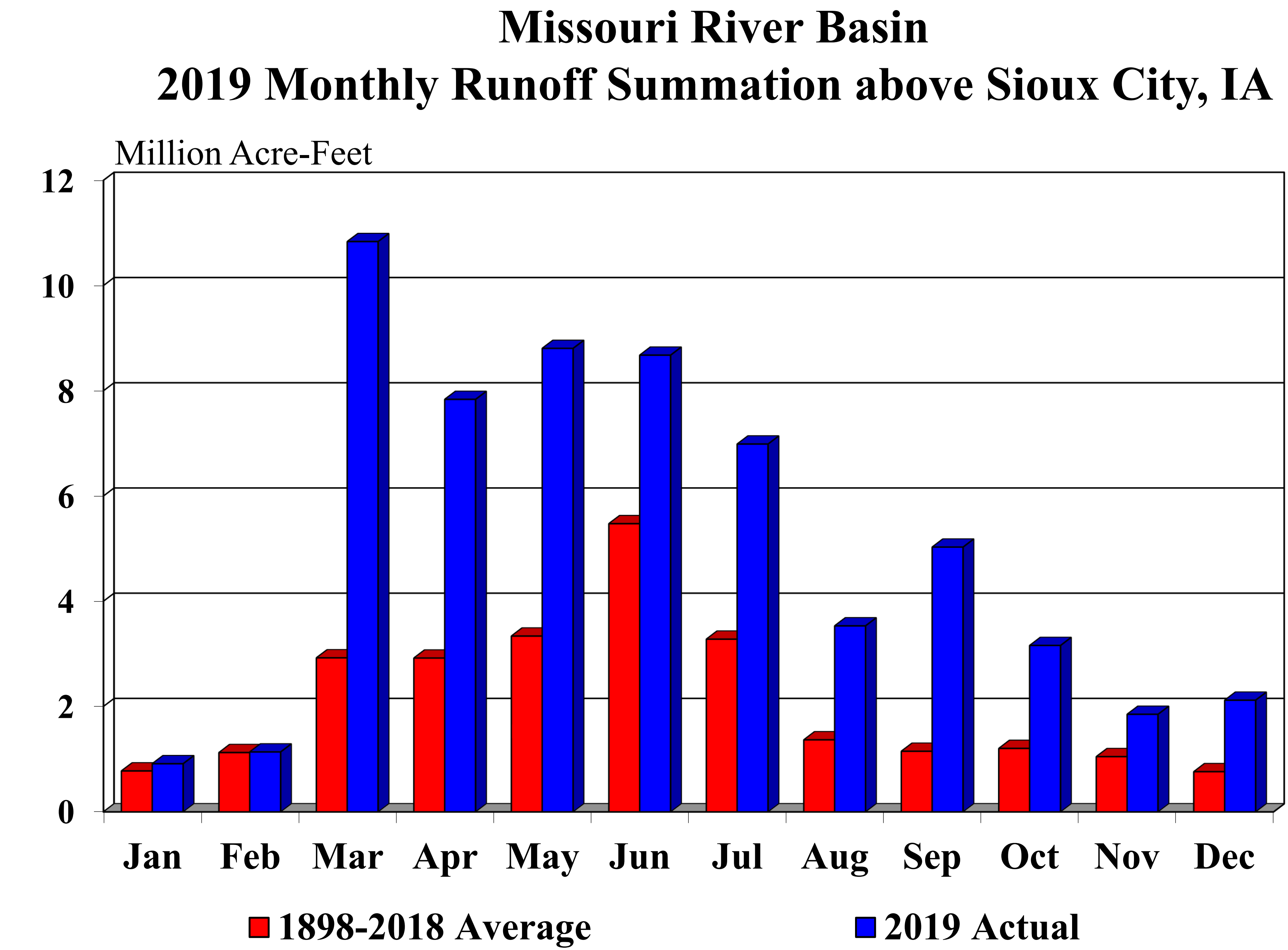


Figure 26. Missouri River Basin 2019 monthly runoff summation above Sioux City, IA.

C. System Regulation – January to December 2019

1. Basin Conditions and System Regulation

At the beginning of the 2019 runoff season, System storage was at 56.1 MAF, the base of the Annual Flood Control and Multiple Use Zone. From June 6 to August 6, water was stored in the System's Exclusive Flood Control Zone. Much above average releases were necessary from all System projects to manage the near-record upper Basin runoff and prepare the System for the 2020 runoff season.

a. Conditions in January and February

System storage reached 56.1 MAF, the base of the Annual Flood Control and Multiple Use Zone on January 29, which means that all stored flood waters from the 2018 runoff year were evacuated before the start of the 2019 runoff year. System storage remained at or near the base of the Annual Flood Control and Multiple Use Zone during February. Upper Basin runoff in the reaches above Gavins Point was below average in January and February (see ***Table 4***), but was well-above average in the Sioux City reach. The January 1 mountain SWE totals for the Fort Peck and Fort Peck to Garrison reaches were 79 percent and 83 percent of average, respectively. The February 1 mountain SWE was 83 percent of average in the Fort Peck reach and 85 percent of average in the Fort Peck to Garrison reach (see ***Table 3***). On February 1, plains snow was concentrated in central and eastern North Dakota and northeastern South Dakota. During February, heavy accumulations of snow and expansion of the snowpack were observed across the upper Basin, Nebraska and western Iowa (see ***Figure 7*** and ***Figure 10***).

b. Conditions on March 1

On March 1 the System storage was 56.1 MAF, at the base of the Annual Flood Control and Multiple Use Zone. There was moderate-to-heavy plains snow cover over the upper Basin, with the greatest SWE amounts concentrated in North Dakota, South Dakota and western Iowa. Following a significant winter storm that ended on March 10, the plains SWE volume and areal extent peaked (see ***Figure 10***). Soil moisture conditions in early March were wetter than normal in much of Montana, Wyoming, Nebraska, southeastern South Dakota, Iowa, Kansas and northern Missouri (see ***Figure 3***). During February the mountainous areas received above-normal precipitation and below-normal temperatures. On March 1, the mountain SWE had increased to 107 percent of average in the Fort Peck reach and 101 percent of average in the Fort Peck to Garrison reach (see ***Table 3***). The March 1 annual runoff forecast was 28.4 MAF, 112 percent of average. The above-average calendar year runoff forecast was based on 1) significant development of plains snowpack during February, 2) an increase in the mountain snowpack, and 3) wetter-than-normal soil conditions in Montana, Wyoming and southeastern South Dakota.

Snowmelt commenced in Nebraska and western Iowa on March 9 prior to the development of the 'bomb cyclone', which moved through the central portion of the Missouri River Basin several days afterwards. The bomb cyclone's impact to upper and lower Basin runoff was immediate as the Missouri River and its tributaries rose rapidly in the Fort Randall, Gavins Point and Sioux City reaches as the snow melted and heavy rainfall occurred simultaneously from

March 12-15. Record high unregulated streamflow and historic flooding occurred on the Niobrara River and several smaller tributaries, all of which flow into the Gavins Point reservoir. In response to the record inflow into the Gavins Point reservoir, the MRBWM office reduced Fort Randall releases to 0 cfs for most of the period from March 13-22 to better manage the Gavins Point reservoir pool rise. Even with the reduction of Fort Randall releases to 0 cfs, record inflows into Gavins Point, primarily from the Niobrara River and tributaries between Fort Randall and Gavins Point, were observed. All 14 Gavins Point spillway gates were raised to create additional reservoir storage (i.e., surcharged). The surcharge operations allowed the Gavins Point reservoir to rise to a record elevation of 1212.3 feet, 2.3 feet above the top of the Exclusive Flood Control Zone. Even with the increased reservoir storage, the MRBWM office needed to increase Gavins Point releases to an hourly peak discharge of 100,000 cfs and an average daily discharge of 90,500 cfs on March 15 to prevent the pool level from rising above the top of the raised spillway gates.

The March 15 System storage check of 56.6 MAF set navigation flow support to the full service flow level for the first half of the navigation season, per the Master Manual. Storage levels in the lower three System projects – Big Bend, Fort Randall and Gavins Point – and anticipated runoff into those reservoirs led the MRBWM office to increase the service level to "expanded" levels to start initiating flood storage evacuation. Starting flood storage evacuation early in the runoff season allows for the maximum amount of time to evacuate stored flood waters and reduces the peak System releases over the period. On March 18, based on a mid-March calendar year runoff forecast, current System and tributary storage levels, and Plate VI-1 of the Master Manual, the service level was increased from 35,000 cfs to 45,000 cfs to begin evacuating stored flood waters and ready the System for the forecasted higher-than-average upper Basin runoff. Gavins Point releases were steadily reduced from the 100,000-cfs peak on March 15 to 24,000 cfs on March 20 as downstream tributary and Missouri River flows subsided. Starting on March 25 the System release at Gavins Point Dam was increased from 24,000 cfs to 39,000 cfs over a 7-day period to begin evacuating stored flood waters in the System, and to provide some operational flexibility for the remainder of the runoff season.

As a result of the extreme winter weather conditions in March, Fort Randall and Gavins Point received record high volumes of runoff as well as in tributaries in the Sioux City reach. March runoff volumes in the Garrison and Oahe reaches were the second highest March volumes on record. March upper Basin runoff was a record 10.8 MAF, 370 percent of average, 3.4 MAF more than the 1972 previous record March volume.

c. Conditions on April 1

System storage on April 1 was 62.6 MAF, 6.5 MAF above the base of the Annual Flood Control and Multiple Use Zone. The April 1 upper Basin runoff forecast was 38.2 MAF, 151 percent of average. On April 1, the mountain SWE was 96 percent of the April 1 average above Fort Peck and 92 percent of average in the Fort Peck to Garrison reach.

Based on the April 1 calendar year runoff forecast above Gavins Point, System and tributary storage levels, and Plate VI-1 of the Master Manual, the service level was increased another 5,000 cfs – from 45,000 cfs to 50,000 cfs – on April 1. System releases at Gavins Point were steadily increased to 55,000 cfs by April 8 to maintain operational flexibility and lessen the rise in System storage.

By April 22, System storage had reached 64.7 MAF, occupying 8.6 MAF of the designated 16.3 MAF flood control storage space. The upper Basin runoff had lessened, resulting in reservoir inflows nearly matching the 55,000 cfs System release at Gavins Point. As a result, System storage remained near 64.7 MAF through the rest of April.

The mountain snowpack peaked around its normal time of the year. The mountain SWE in the Fort Peck reach peaked on April 18 at 105 percent of average. In the Fort Peck to Garrison reach, the mountain SWE peaked on April 17 at 104 percent of average (see ***Table 3***).

d. Conditions on May 1

The May 1 annual runoff forecast was 43.2 MAF, 170 percent of average. The May 1 forecast reflected 1) record high January-April accumulated runoff into the System, 2) much wetter-than-normal soil moisture conditions in Montana, Wyoming, South Dakota and Nebraska; and 3) the CPC outlook indicating increased chances for above normal May-June-July precipitation in the upper Basin.

Based on the May 1 calendar year runoff forecast above Gavins Point, System and tributary storage levels, and Plate VI-1 of the Master Manual, the service level was increased another 5,000 cfs – from 50,000 cfs to 55,000 cfs – on May 1. System releases at Gavins Point were maintained at 55,000 cfs.

Due to the record May precipitation in the states of Nebraska, Kansas and Missouri, tributary and Missouri River flows remained in moderate to major flood stage through May. Heavy rainfall in these states near the end of May resulted in a second, higher flood peak on the Missouri River from Waverly, MO to Hermann, MO. Meanwhile, accumulated precipitation in South Dakota and Iowa ranked in the top five wettest Mays. As a result of the heavy precipitation in May, upper Basin runoff was 8.8 MAF, 262 percent of average, ranking as the second highest May runoff summation behind the 9.2 MAF observed in 2011. As the lower Missouri River flood peaks crested, Gavins Point releases were increased to 60,000 cfs on May 23. Releases were then stepped up to 70,000 cfs by May 29, as System storage approached the base of the Exclusive Flood Control Zone.

e. Conditions in June and July

The June 1 System storage was 67.4 MAF, 0.3 MAF below the base of the Exclusive Flood Control Zone. The June 1 annual runoff forecast was 50.0 MAF, 197 percent of average, placing the 2019 forecasted runoff as the second highest runoff summation in 121 years of record-keeping, 1.0 MAF more than the 1997 upper Basin runoff of 49.0 MAF.

Based on the June 1 calendar year runoff forecast above Gavins Point, System and tributary storage levels, and Plate VI-1 of the Master Manual, the service level was increased 15,000 cfs, from 55,000 cfs to 70,000 cfs. The record or near-record rainfall in May resulted in fully saturated soils in much of the Missouri River Basin. Thus, the inflows in the lower four System reservoirs – Oahe, Big Bend, Fort Randall and Gavins Point – were significantly higher than average. To slow the rate of rise of the pool levels in the Oahe and Fort Randall reservoirs, which had most of their available flood control storage already occupied, Gavins Point releases were increased to 75,000 cfs on June 1. This increase in Gavins Point releases, which allowed for increased releases from Oahe, Big Bend and Fort Randall, resulted in the decline of pool elevations in the Oahe and Fort Randall reservoirs. On June 6, System storage reached 67.7 MAF, which is the base of the Exclusive Flood Control Zone. The 75,000-cfs Gavins Point release was continued until it was stepped down to 70,000 cfs on June 28. From June 1-28, the increased releases from the four lower System projects resulted in the Oahe and Fort Randall pool elevations lowering about 2 feet and 7 feet, respectively, and provided about 1.5 MAF of flood control storage in those two reservoirs.

June precipitation was about normal in the Missouri River Basin. However, June runoff was well-above average in all reservoir reaches of the upper Basin, due to the mountain snowmelt runoff, wet soil moisture conditions, and the continuing runoff from the much-above normal May rainfall. The June runoff summation above Sioux City was 8.7 MAF, 157 percent of average. System storage increased slightly during June, reaching 68.0 MAF on July 1, filling 0.3 MAF of the System's 4.7-MAF Exclusive Flood Control Zone.

The July 1 annual runoff forecast was updated to 49.9 MAF, 197 percent of average. The System release from Gavins Point was maintained at 70,000 cfs during July. July precipitation was over 150 percent of normal from southern Montana through northeastern Wyoming, South Dakota and northwestern Iowa. The above-normal precipitation resulted in above-average inflows into Oahe and Fort Randall. The July upper Basin runoff was 7.0 MAF, more than two times average. Runoff was more than five times average in the Oahe reach and almost seven times average in the Fort Randall reach. As a result, System storage increased through mid-July and peaked at 68.5 MAF, 0.8 MAF into the 4.7-MAF Exclusive Flood Control Zone, on July 20.

f. Conditions from August through December

August 1 System storage was 68.0 MAF, 0.3 MAF above the base of the 4.7-MAF Exclusive Flood Control Zone. The August 1 annual runoff forecast was increased to 52.9 MAF, 209 percent of average due to above-average runoff in the upper Basin and a seasonal climate outlook that signaled above-normal precipitation during the fall. August precipitation was well-above normal throughout the upper Basin and much of the lower Basin, resulting in more than two times average runoff in the upper Basin. Gavins Point releases were held steady at 70,000 cfs during August. The System storage declined and exited the Exclusive Flood Control Zone on August 6, 61 days after it entered the zone.

September 1 System storage was 65.6 MAF, 9.5 MAF above the base of the 11.6-MAF Annual Flood Control and Multiple Use Zone. Based on the September 1 System storage check, the Gavins Point winter release would be at least 17,000 cfs. The September 1 annual runoff forecast was 54.6 MAF, 215 percent of average. September precipitation was more than two times normal over much of the upper Basin. Heavy precipitation occurred over northeastern Montana and central North Dakota during the last two weeks of September. Very heavy precipitation ranging from 6 to more than 10 inches occurred from north-central Nebraska to eastern South Dakota in early September (see ***Figure 23***). As a result, the James River at Scotland, SD experienced a record high discharge of 59,000 cfs and stage of 22.2 feet on September 14. Because of the extremely high tributary inflows entering the Missouri River downstream of Gavins Point Dam, the MRBWM office reduced the Gavins Point release to 60,000 cfs from September 15-18 to provide some downstream flood relief in the locations where Missouri River levee system restoration was ongoing. From September 18-21, the Gavins Point release was stepped up to 80,000 cfs to continue evacuating stored flood waters. The September runoff above Sioux City was 5.0 MAF, 435 percent of average, and nearly twice the previous record September runoff. September runoff was the record highest in the Garrison, Fort Randall, Gavins Point and Sioux City reaches.

The October 1 System storage was 64.0 MAF, 7.9 MAF above the base of the Annual Flood Control and Multiple Use Zone. The October 1 annual runoff forecast was 61.0 MAF, 241 percent of average and equal to the record upper Basin runoff that occurred in 2011. Areas of above-normal precipitation continued in the upper Basin during October, November and December, resulting in the October runoff summation ranking as the second highest, the November runoff summation ranking as the third highest, and the December runoff ranking as the highest in 121 years of record-keeping.

The 80,000-cfs Gavins Point release was continued during October and into November to evacuate stored flood waters prior to the 2020 runoff season. On November 1, System storage was 60.9 MAF, 4.8 MAF above the base of the Annual Flood Control and Multiple Use Zone. The System release was reduced to 75,000 cfs on November 23, then stepped down to 70,000 cfs on November 30. On December 1, System storage was 57.5 MAF, 1.4 MAF above the base of the Annual Flood Control and Multiple Use Zone. On December 3, the System release was reduced to 65,000 cfs, and then stepped down to 60,000 cfs on December 4. For each following day the Gavins Point release was stepped down 3,000 cfs per day until reaching a release rate of 27,000 cfs on December 15. The Gavins Point release was held steady at 27,000 cfs through the end of the calendar year. The average December release of 37,000 in 2019 was nearly double the average long-term December release of 19,800 cfs. These above-average releases were necessary to continue evacuating the remaining stored flood water and start the 2020 runoff season with all 16.3 MAF of designated flood control storage available. By December 31, System storage was 56.8 MAF, 0.7 MAF above the base of the Annual Flood Control and Multiple Use Zone. On January 20, 2020, System storage was 56.1 MAF, which means that all 2019 stored flood waters were evacuated prior to the start of the 2020 runoff season, which begins on or about March 1.

2. Fort Peck Regulation – January to December 2019

a. General

Fort Peck, the third largest Corps storage reservoir, serves all authorized purposes. Fort Peck's primary functions are (1) to capture the snowmelt runoff and localized rainfall runoff from the large drainage area above Fort Peck Dam, which are metered out at controlled release rates to meet the authorized purposes while reducing flood damages in the Fort Peck to Garrison reach; (2) to serve as a secondary storage location for water accumulated in the System reservoirs from reduced System releases due to major downstream flood control regulation, thus helping to alleviate large pool increases in Garrison, Oahe and Fort Randall; and (3) to provide the water needed to meet all authorized purposes that draft storage during low-water years.

Table 7 lists the average monthly inflows and releases and the end-of-month (EOM) pool elevation for Fort Peck for 2018 and 2019 as well as the averages since the System first filled in 1967.

Table 7
Fort Peck – Inflows, Releases and Elevations

Month	Monthly Inflow (cfs)			Monthly Release (cfs)			EOM Elevation (feet)		
	2019	2018	1967-2018	2019	2018	1967-2018	2019	2018	1967-2018
January	6,900	6,400	7,100	11,800	9,900	10,300	2235.8	2234.9	2227.8
February	7,000	8,000	8,600	12,200	10,400	10,600	2234.4	2233.9	2227.2
March	20,200	16,000	11,700	6,900	8,300	7,700	2238.1	2236.0	2228.3
April	16,300	24,000*	10,400	6,600	9,400	7,300	2240.6	2239.9	2229.1
May	20,400	31,700	15,800	8,200	14,200	9,100	2243.8	2244.4	2230.9
June	20,300	32,500	19,500	9,000	19,400	10,600	2246.4	2247.5	2233.2
July	13,300	13,600	11,900	12,900	17,400	10,500	2246.2	2246.1	2233.2
August	8,700	7,600	7,900	15,100	16,000	10,200	2244.1	2243.5	2232.1
September	11,300	7,800	7,700	15,000	14,300	8,900	2242.8	2241.4	2231.2
October	9,600	7,400	7,400	14,700	11,800	7,800	2240.7	2240.0	2230.7
November	9,700	7,500	7,100	15,300	11,700	8,100	2238.8	2238.6	2230.1
December	8,500	7,700	6,600	13,700*	11,600	9,200	2237.0	2237.2	2229.0
Annual	**12,700**	**14,200**	**10,100**	**11,800**	**12,900**	**9,200**			

*monthly maximum of record

b. Winter Season 2018-19

The Fort Peck reservoir level was at elevation 2238.6 feet on December 1, 2018, 4.6 feet above the base of the Annual Flood Control and Multiple Use Zone and 2.6 feet above the previous year's level. The reservoir reached elevation 2234.3 feet, 0.3 foot above the base of the

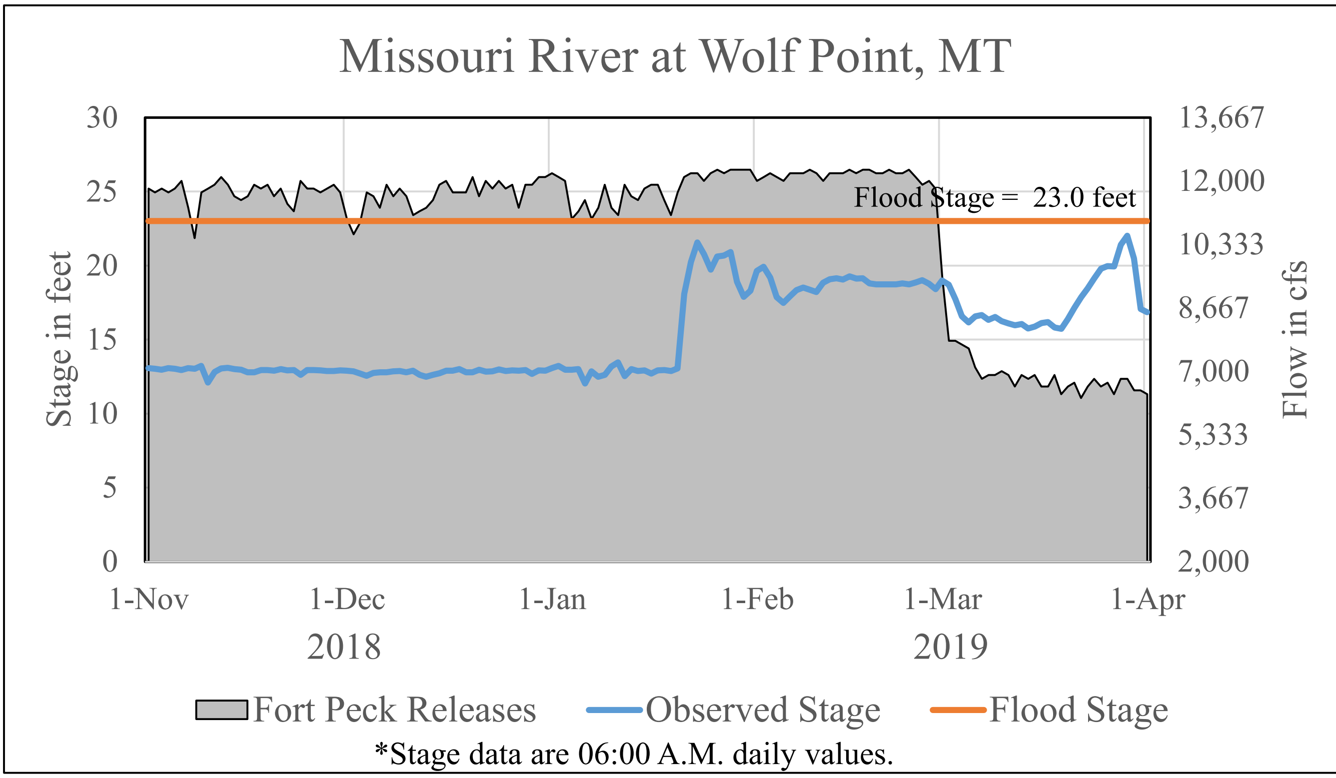
Annual Flood Control Multiple Use Zone, on March 5. During the winter season the average monthly releases from Fort Peck were above average: December 2018 was 11,600 cfs (average is 9,200 cfs); January was 11,800 cfs (average is 10,300 cfs); and February was 12,200 cfs (average is 10,600 cfs). The Fort Peck reservoir froze over on February 4 and was free of ice on April 16. While the free-of-ice date was later than usual, it was more than three weeks earlier than the record of May 9, set in 1950.

c. Winter River and Ice Conditions below Fort Peck

No special release reductions were required due to ice-jam flooding downstream of Fort Peck. The sub-zero (deg F) temperatures experienced in mid-January produced an ice-cover formation on the Missouri River downstream of Fort Peck. When the Missouri River froze over, the stage rose over 9 feet in the Wolf Point, MT reach from January 19-22 (see ***Figure 27***). After the freeze-in, the stage dropped and varied from about 17 to 21 feet until March 3, when it dropped to near 16 feet. At the end of March, following a period of warm air temperatures, the Missouri River at Wolf Point rose to an hourly peak of 23.6 feet on March 29 and then dropped to under 17 feet on March 31. During this time the river ice in the Missouri River and its tributaries was actively melting and breaking up, which resulted in a temporary rise in stages and flows on the Missouri River. The USGS began reporting non-ice-affected Missouri River flows at Wolf Point beginning on April 4. The Missouri River was above the 23-foot flood stage at Wolf Point on March 29 for about 4 hours. No reports of ice-affected flooding on the Missouri River reach below Fort Peck were recorded during the 2018-19 winter season.

d. Spring Open Water Season 2019

Warmer-than-normal temperatures limited plains snowpack development from November 2018 through January 2019 despite above-normal precipitation in Montana. By February 1, only trace amounts of SWE existed in Montana. However, a more active weather pattern and temperature departures in Montana ranging from 9 to 12 deg F below normal brought well-above average snowfall to the upper Basin. By March 10, the snowfall extent and SWE was at its seasonal maximum (see ***Figure 10***). The NOHRSC snow model indicated that SWE amounts ranged from 1 to 3 inches over much of Montana and western North Dakota. Plains snowpack began to melt during March, which led to above-average inflows during March and April. The mountain snowpack above Fort Peck was near average and peaked on April 18 at 105 percent of the long-term average. Melting of the mountain snowpack, coupled with periodic rainfall during May, kept inflows above average during May. As the runoff from the mountain snowpack slowed, near-average preciptation across Montana caused inflows to moderate in June. Average monthly inflows to the reservoir were 16,300 cfs (157 percent of average) in April, 20,400 cfs (129 percent of average) in May and 20,300 cfs (104 percent of average) in June. Releases from Fort Peck were below average during the spring months as reservoirs downstream of Fort Peck captured runoff from the melting plains snowpack. Fort Peck releases averaged 6,600 cfs (90 percent of average) in April, 8,200 cfs (90 percent of average) in May, and 9,000 cfs (85 percent of average) in June. Fort Peck reservoir rose 8.3 feet from its March 31 elevation of 2238.1 feet to 2246.4 feet at the end of June, 0.4 foot above the base of the Exclusive Flood Control Zone. Fort Peck reservoir rose 5.7 feet during the critical fish spawning period from 2238.1 feet (March 31) to 2243.8 feet (May 31).



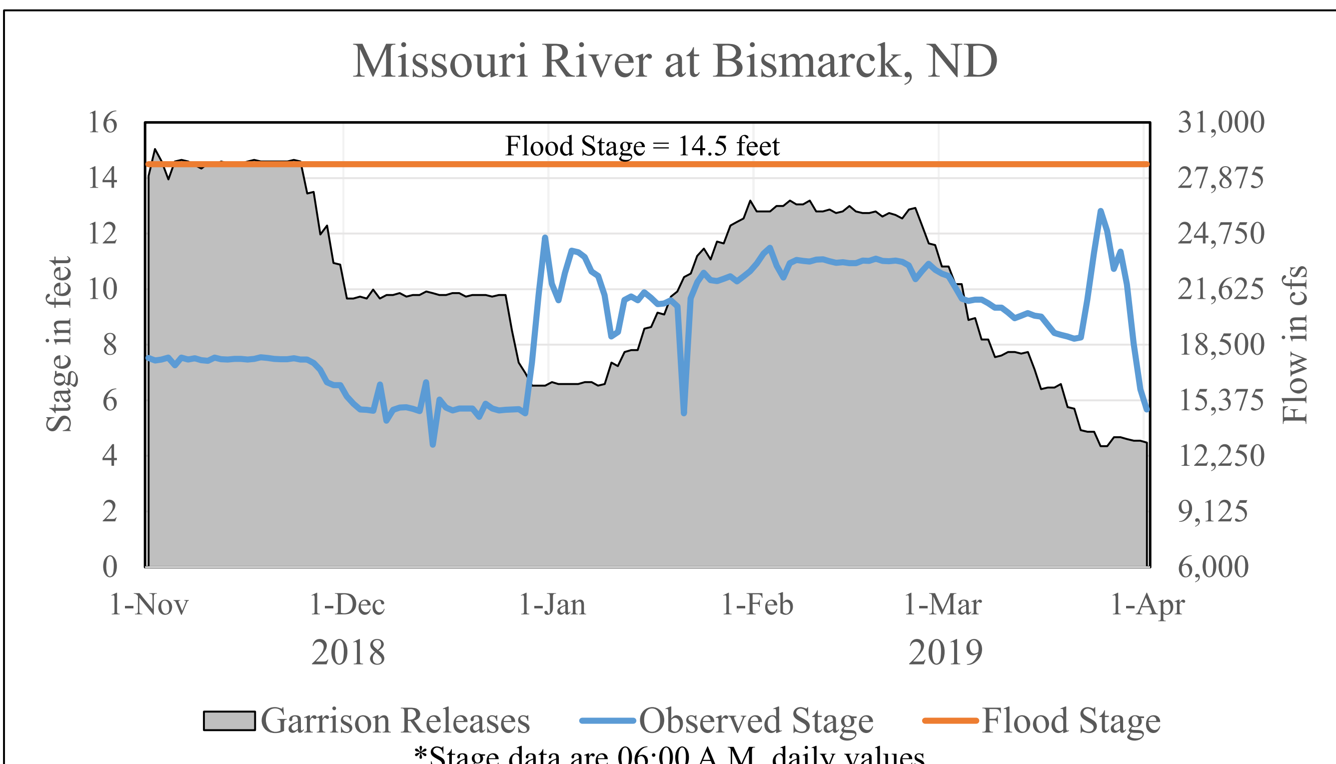


Figure 27. Observed Winter Ice Season Stages at Wolf Point, MT and Bismarck, ND and Fort Peck and Garrison releases.

e. Summer Open Water Season 2019

Average monthly inflows averaged 13,300 cfs (112 percent of average) during July and 8,700 cfs (110 percent of average) during August. Above-average precipitation occurred across much of Montana, especially in eastern Montana, which had areas of 4 to 8 inches departure from normal precipitation. This led to above-average September inflows. Fort Peck inflows averaged 11,300 cfs (147 percent of average) during September. Summer releases were also above average. Average monthly releases were 12,900 cfs (123 percent of average) during July, 15,100 cfs (148 percent of average) during August, and 15,000 cfs (169 percent of average) during September. The reservoir level peaked in early July at 2246.8 feet and steadily decreased over the remainder of the summer months. Over the 3-month period the reservoir level decreased 3.6 feet from 2246.4 feet (June 30) to 2242.8 feet (September 30).

f. Fall Open Water Season 2019

Releases during the fall continued to be above average as the remaining stored flood waters were evacuated and storage in the upper three reservoirs was balanced. Average monthly releases were 14,700 cfs in October (188 percent of average), 15,300 cfs in November (189 percent of average) and 13,700 cfs in December (149 percent of average). Inflows also remained above average, averaging 9,600 cfs in October (130 percent of average), 9,700 cfs in November (137 percent of average), and 8,500 cfs in December (129 percent of average). The pool elevation decreased 5.8 feet over the 3-month period from 2242.8 feet (September 30) to 2237.0 feet (December 31), 3.0 feet above the base of the Annual Flood Control and Multiple Use Zone.

g. Summary

The highest 2019 Fort Peck midnight pool elevation occurred on July 10 at 2246.8 feet, 0.8 foot above the base of the 4-foot Exclusive Flood Control Zone. The lowest 2019 midnight pool elevation was 2234.3 feet on March 3, 0.3 foot above the base of the Annual Flood Control and Multiple Use Zone. The 2019 average daily inflow of 12,700 cfs was 126 percent of average. The 2019 average daily release of 11,800 cfs was 128 percent of average.

3. Garrison Regulation – January to December 2019

a. General

Garrison, the largest Corps storage reservoir, is another key component in the regulation of the System. Its primary functions are (1) to capture the snowmelt runoff and localized rainfall runoff from the large drainage area between the Fort Peck and Garrison dams, which are metered out at controlled release rates to meet the authorized purposes while reducing flood damages in the Garrison to Oahe reach, particularly the urban Bismarck area; (2) to serve as a secondary storage location for water accumulated in the System from reduced System releases due to major downstream flood control regulation, thus helping to alleviate large pool increases in Oahe and Fort Randall; and (3) to provide water needed to meet all authorized purposes that draft storage during low-water years.

Table 8 lists the average monthly inflows and releases and the EOM pool elevation for Garrison for 2018 and 2019 as well as the averages since the System first filled in 1967.

Table 8
Garrison – Inflows, Releases and Elevations

Month	Monthly Inflow (cfs)			Monthly Release (cfs)			EOM Elevation (feet)		
	2019	2018	1967-2018	2019	2018	1967-2018	2019	2018	1967-2018
January	16,200	16,500	15,100	20,200	24,200	22,200	1838.9	1839.2	1832.4
February	17,700	18,500	18,400	25,900	25,200	23,300	1837.3	1837.9	1831.5
March	44,900	28,800	26,500	16,700	22,400	19,000	1842.6	1839.0	1832.9
April	34,800	46,800	23,300	13,400	28,100	19,100	1846.4	1842.4	1833.6
May	32,200	61,200	30,500	23,500	36,800	22,100	1847.8	1846.7	1835.1
June	56,700	87,000	48,700	31,300	48,700	25,600	1851.8	1852.8	1839.3
July	46,800	47,200	33,200	46,400	58,700	26,600	1851.6	1850.7	1840.3
August	27,300	25,000	18,600	46,300	47,100	25,500	1847.9	1846.5	1838.5
September	35,900	23,300	17,100	45,900	37,300	21,200	1845.7	1843.5	1837.2
October	30,400	21,100	17,300	47,000	29,300	19,000	1842.4	1841.7	1836.6
November	26,700	20,800	16,000	42,500*	28,000	19,700	1839.1	1840.2	1835.5
December	22,800*	19,400	13,900	20,500	20,500	19,600	1839.2	1839.6	1834.0
Annual	**32,700**	**34,600**	**23,200**	**31,600**	**33,900**	**21,900**			

*monthly maximum of record

b. Winter Season 2018-19

The Garrison reservoir level was at elevation 1840.2 feet on December 1, 2018, 2.7 feet above the base of the Annual Flood Control and Multiple Use Zone and 1.6 feet below the previous year's level. The reservoir level declined through December and January and reached 1836.9 feet, 0.6 foot below the base of the Annual Flood Control and Multiple Use Zone, on March 14. The Garrison average monthly winter releases were above average for December, below average for January and above average for February: December 2018 was 20,500 cfs (average is 19,600 cfs); January was 20,200 cfs (average is 22,200 cfs); and February was 25,900 cfs (average is 23,300 cfs). The Garrison reservoir froze over on January 12 and was free of ice on April 29. While the free-of-ice date was later than usual, it was more than two weeks earlier than the record of May 17, set in 1979.

c. Winter River and Ice Conditions Below Garrison

At Bismarck, ND the season initial river ice formation occurred December 28-30, 2018. During this 3-day period, the Missouri River stage rose from approximately 6 feet to 12 feet (see ***Figure 27***). During the winter the stages ranged from about 8 feet to 12 feet. Warmer air temperatures in mid-March resulted in increased tributary flows and melting ice; the Missouri

River at Bismarck stage rose about 5 feet from March 22–26 and peaked near 13.0 feet. Two winter-season Missouri River stage peaks were observed at Bismarck: 11.9 feet on December 31 and 13.0 feet on March 25. The peak stages were more than 1.5 feet below the Bismarck flood stage of 14.5 feet and below the Corps' winter freeze-in maximum target stage of 13.0 feet. No reports of ice-affected flooding on the Missouri River below Garrison were recorded during the 2018-19 winter season.

d. Spring Open Water Season 2019

A light plains snowpack was present in the reach between Fort Peck and Garrison. By February 1, the NOHRSC snow model indicated that modeled SWE amounts ranged from trace to 1 inch amounts in eastern Montana and western North Dakota. As with the plains snowpack above Fort Peck, cold temperatures and above-normal precipitation during February and early March increased the plains snowpack across much of Montana and North Dakota (see ***Figure 10***). By March 10, 1 to 3 inches of SWE covered much of Montana and western North Dakota. Inflows into Garrison were above average in April as the plains snowpack began to melt during March and April. The mountain snowpack in the Fort Peck to Garrison reach was near average, peaking at 104 percent of average on April 17. The melting mountain snowpack resulted in near-average inflows during May and June. Average monthly inflows to the reservoir were 34,800 cfs (149 percent of average) in April, 32,200 cfs (106 percent of average) in May and 56,700 cfs (116 percent of average) in June. Because of the high pool levels in the Oahe and Fort Randall reservoirs, releases from Garrison were made at below-average rates in April: 13,400 cfs or 70 percent of average. The April 1 monthly reservoir studies forecasted a spring peak pool elevation of 1616.0 feet at Oahe, 1.0 foot below the base of its 3-foot Exclusive Flood Control Zone, and 1360.5 feet at Fort Randall, 4.5 feet below the base of its Exclusive Flood Control Zone. Observed April runoff into Garrison was more than forecast and the Oahe and Fort Randall reservoirs began to decline in late April. Garrison releases were increased in early May and then reduced again late in the month due to increased runoff into Oahe and Fort Randall. Releases averaged 23,500 cfs (106 percent of average) in May. Per the June 1 monthly reservoir studies, the Garrison pool elevation was forecast to peak near 1852.0 feet, 2.0 feet into its 4-foot Exclusive Flood Control Zone. Garrison releases were increased during June and averaged 31,300 cfs (122 percent of average). The Garrison reservoir level rose 9.2 feet from its March 31 elevation of 1842.6 feet to 1851.8 feet at the end of June, filling all 12.5 feet of the Annual Flood Control and Multiple Use Zone (1837.5 to 1850.0 feet) and 1.8 feet of the 4-foot Exclusive Flood Control Zone (1850.0 to 1854.0 feet). The Garrison reservoir level rose 5.2 feet during the critical fish spawning period, from 1842.6 feet (March 31) to 1847.8 feet (May 31).

e. Summer Open Water Season 2019

Inflows into the Garrison reservoir peaked in June but remained above average during the summer months. Inflows averaged 46,800 cfs during July (141 percent of average) and 27,300 cfs during August (147 percent of average). Widespread rainfall during September across central and western North Dakota and eastern Montana, 4 to 8 inches above normal, increased inflows during September, which averaged 35,900 cfs, 210 percent of average. Releases remained high during the summer months to evacuate all stored flood waters. Releases averaged 46,400 cfs (141 percent of average), 46,300 cfs (147 percent of average), and 45,900 cfs (210 percent of average) during July, August and September, respectively. During the 3-month period, the pool level crested at 1852.5 feet on July 9, 2.5 feet into the 4-foot Exclusive Flood Control Zone. Following the crest, the Garrison pool slowly declined 6.8 feet to 1845.7 feet at the end of September. Due to the higher-than-average releases, hydropower peaking was eliminated during the summer months. A daily peaking pattern was not established at Garrison to protect T&E species nesting on sandbars below the project.

f. Fall Open Water Season 2019

Inflows remained above average during the October-December period, 30,400 cfs (176 percent of average) in October, 26,700 cfs (167 percent of average) in November and 22,800 cfs (164 percent of average) in December. Releases also remained above average in October (47,000 cfs; 247 percent of average), November (42,500 cfs; 216 percent of average) and December (20,500 cfs; 105 percent of average). Releases were decreased in December in anticipation of the freeze-in of the Missouri River between Washburn and Bismarck, ND, which occurred on December 12. The December 31 Garrison pool elevation was 1839.2 feet, 1.7 feet above the base of the Annual Flood Control and Multiple Use Zone.

g. Lake Audubon / Snake Creek Embankment

During the 2000-2007 drought, a restriction was put in place to limit the water level difference between Lake Audubon and Lake Sakakawea to 43 feet. This restriction required a pool restriction for Lake Audubon as a result of an underseepage evaluation of the Lake Audubon embankment by the Corps' Omaha District. Since the Garrison reservoir has returned to more average elevations following the 8-year drought, this water level difference restriction has not been an issue. Lake Audubon was drawn down to a winter level of 1845.0 feet in the fall.

h. Summary

The Garrison pool elevation peaked at 1852.5 feet on July 9 at midnight, occupying 2.5 feet of the 4-foot Exclusive Flood Control Zone. The lowest Garrison midnight pool level during 2019 occurred on March 15 at 1836.9 feet, 0.6 foot below the base of the Annual Flood Control and Multiple Use Zone. The average annual inflow of 32,700 cfs was 141 percent of average. The average annual release of 31,600 cfs was 144 percent of average.

4. Oahe and Big Bend Regulation – January to December 2019

a. General

Oahe, the second largest Corps storage reservoir, serves all authorized purposes. Oahe's primary functions are (1) to capture snowmelt and localized rainfall runoff from the large drainage area between the Garrison and Oahe dams, which are metered out at controlled release rates to meet the authorized purposes, while reducing flood damages in the Oahe to Big Bend reach, especially in the urban Pierre and Fort Pierre areas; (2) to serve as a primary storage location for water accumulated in the System from reduced System releases due to major downstream flood control regulation, thus helping to alleviate large reservoir level increases in Big Bend, Fort Randall and Gavins Point; and (3) to provide water needed to meet all authorized purposes that draft storage during low-water years, particularly downstream water supply and navigation. In addition, hourly and daily releases from Big Bend and Oahe fluctuate widely to meet varying power loads. Over the long term, their release rates are geared to back up navigation releases from Fort Randall and Gavins Point in addition to providing storage space to permit a smooth transition in the scheduled annual fall drawdown of Fort Randall. Big Bend, with less than 2 MAF of total storage, is primarily used for hydropower production, so releases from Oahe are generally passed directly through Big Bend.

Table 9 lists the average monthly inflows and releases and the EOM pool elevation for Oahe for 2018 and 2019 as well as the averages since the System first filled in 1967.

Table 9
Oahe – Inflows, Releases and Elevations

Month	Monthly Inflow (cfs)			Monthly Release (cfs)			EOM Elevation (feet)		
	2019	2018	1967-2018	2019	2018	1967-2018	2019	2018	1967-2018
January	18,500	23,300	22,600	24,900	24,600	20,900	1605.9	1606.4	1599.5
February	27,800	26,300	26,600	22,100	17,600	18,200	1606.8	1607.8	1601.1
March	52,400	28,400	30,400	9,500	21,000	18,300	1614.7	1609.1	1603.4
April	40,700	33,600	27,100	30,200	27,900	21,200	1616.4	1610.3	1604.4
May	48,700	40,400	28,600	35,900	34,100	22,200	1618.8*	1611.1	1605.5
June	37,900	54,000	31,400	49,900	35,600	26,900	1616.6	1614.3	1605.9
July	60,100	61,200	29,100	55,500	43,300	31,200	1616.9	1617.2	1605.1
August	52,100	48,200	27,100	57,000	53,200	33,800	1615.7	1615.9	1603.3
September	53,700*	39,600	22,900	55,600	47,800	29,900	1615.1	1614.0	1601.4
October	54,300*	30,100	20,600	62,200*	45,900	24,100	1613.1	1610.6	1600.3
November	47,900*	29,200	21,100	64,900*	45,600	23,000	1610.1	1607.2	1599.7
December	24,800	23,200	20,000	31,800	22,000	20,600	1607.9	1607.2	1599.3
Annual	**43,200**	**36,500**	**25,600**	**41,600**	**34,900**	**24,200**			

*monthly maximum of record

A settlement agreement was approved in an order of dismissal by the United States District Court, District of South Dakota on August 8, 2003, in the case of Lower Brule Sioux Tribe et al. v. Rumsfeld, et al. (Civil No. 02-3014 (D.S.D.)). The agreement provides that the Corps will consult with the Lower Brule Tribe and the Crow Creek Sioux Tribe during any review and revision of the Master Manual. This agreement also provides that the Corps will coordinate the regulation of Big Bend and the water level of the Big Bend reservoir with the two Tribes to include the following: the Corps will normally strive to maintain a Big Bend pool level between elevation 1419.0 feet and 1421.5 feet and, when the level of the Big Bend reservoir drops below elevation 1419.0 feet or exceeds elevation 1421.5 feet, the Chief of MRBWM will provide notice to such persons as the Tribes shall designate in writing. When it is anticipated that the water level will drop below 1418.0 feet or rise above 1422.0 feet or, in the event the water level falls below 1418.0 feet or rises above 1422.0 feet, the Commander, NWD, or his designee, shall immediately contact the Chairpersons of the Tribes or their designees to notify them of the situation and discuss proposed actions to remedy the situation. During 2019 the Big Bend reservoir level varied in the narrow range between elevations 1419.6 feet to 1421.5 feet. As per the settlement agreement, no additional coordination was necessary.

Table 10 lists the average monthly inflows and releases and the EOM pool elevation for Big Bend for 2018 and 2019 as well as the averages since the System first filled in 1967.

Table 10
Big Bend – Inflows, Releases and Elevations

Month	Monthly Inflow (cfs)			Monthly Release (cfs)			EOM Elevation (feet)		
	2019	2018	1967-2018	2019	2018	1967-2018	2019	2018	1967-2018
January	22,700	22,500	20,400	23,100	23,100	20,400	1420.3	1420.3	1420.5
February	20,900	16,000	18,100	20,300	15,700	18,100	1420.6	1420.5	1420.5
March	15,200	19,900	18,800	15,100	19,600	18,700	1420.7	1420.7	1420.4
April	30,800	26,000	21,400	30,800	25,900	21,000	1420.5	1420.8	1420.5
May	41,500	31,000	22,200	41,300	31,500	22,000	1420.6	1419.8	1420.4
June	45,900	32,500	26,900	45,700	31,600	26,600	1420.3	1420.4	1420.3
July	52,600	39,200	30,300	51,900	38,300	29,900	1420.7	1420.8	1420.3
August	54,600	48,500	32,900	54,100	48,400	32,400	1421.1	1420.4	1420.2
September	54,300	44,300	29,200	53,900	43,200	28,700	1420.7	1421.1	1420.3
October	60,400*	42,700	23,700	60,300*	42,500	23,200	1420.0	1420.9	1420.5
November	62,500*	41,800	22,500	62,400*	42,100	22,400	1420.6	1420.3	1420.4
December	31,400	20,300	20,300	30,600	19,800	20,000	1421.5*	1420.7	1420.5
Annual	**41,100**	**32,100**	**23,900**	**40,800**	**31,800**	**23,600**			

*monthly maximum of record

b. Winter Season 2018-19

No ice-induced flooding problems were experienced downstream of Oahe and Big Bend during the 2018-19 winter. From January 30-February 1, the Oahe releases were reduced from the originally scheduled daily average of 30,000 cfs to daily averages ranging from 22,000 cfs to 25,500 cfs due to ice formation downstream of the project. During this initial ice formation, the Missouri River at Farm Island exceeded its notification stage for short periods. Daily average releases were adjusted as temperatures moderated and the threat of ice-affected flooding diminished. A minimum generation of 100 MW, which is approximately a one-unit release of 8,000 cfs, was implemented at Oahe from January 28-March 9. The one-unit minimum ensures that water is always flowing in the Missouri River downstream of the Oahe Dam, which reduces river ice formation directly below the dam. The Missouri River conditions were closely monitored by Corps staff. The Oahe reservoir froze over on January 30 and was ice free on April 10, which was more than two weeks earlier than the record of April 28, set in 1997.

Big Bend was regulated in the winter season to follow power-peaking requirements and thus hourly releases varied widely. The average daily release during the winter season varied between 3,500 cfs and 34,300 cfs. The Big Bend reservoir froze over on January 2 and was free of ice on April 15, which was less than a week earlier than the record of April 21, set in 2018.

c. Spring Open Water Season 2019

A moderate plains snowpack was present in the Dakotas, especially central and eastern North Dakota and South Dakota. On February 1, the NOHRSC snow model indicated that modeled SWE amounts ranged from 2 to 4 inches in that region. Cold temperatures and above-normal precipitation during February and early March increased the plains snowpack across much of the plains. By March 10, the deepest plains snowpack was present in southern North Dakota and northern South Dakota where 3 to 5 inches of SWE existed (see ***Figure 10***). Moderate SWE amounts ranging from 2 to 3 inches were present throughout much of western North Dakota, southern South Dakota and Nebraska. From March 12-15, a 'bomb cylcone' brought rain to Nebraska and southern South Dakota and snow to central South Dakota. Following the March 12-15 storm, much of the plains snowpack in Nebraska and southern South Dakota had melted, but the snowpack in central South Dakota had increased. The NOHRSC snow model indicated that modeled SWE amounts ranged from 4 to 6 inches over a widespread area of central and eastern South Dakota and south-central and southeastern North Dakota (see ***Figure 12***). The plains snowpack slowly melted during the last half of March and early April and was melted by April 7. The heavy plains snowpack led to above-average inflows into Oahe for all spring months. March, April and May monthly inflows were 52,400 cfs (172 percent of average), 40,700 cfs (150 percent of average) and 48,700 cfs (170 percent of average), respectively. Oahe releases were decreased during March in response to the rainfall and rapid melting of the plains snowpack downstream of Big Bend. Releases from Fort Randall were reduced to 0 cfs for several days during the peak runoff from the March 12-15 event as hourly inflows into Gavins Point peaked near 180,000 cfs. As a result, releases from Oahe and Big Bend were also reduced. March releases averaged 9,500 cfs (52 percent of average). Releases were increased during April and May in order to restore some flexibility to the System – the ability to temporarily reduce releases over the next few months in response to high flows downstream of Gavins Point and maintain some flood storage in the System. Oahe releases averaged 30,200 cfs (142 percent of average) in April and 35,900 cfs (162 percent of average) in May. The Oahe reservoir level rapidly rose nearly 6.0 feet over the last seven days in March. The reservoir rose 12.0 feet between February 28 (1606.8 feet) and May 31 (1618.8). The reservoir pool level peaked at 1618.8 feet on May 31, 1.8 feet into the 3-foot Exclusive Flood Control Zone. The Oahe reservoir rose 4.1 feet during the critical fish spawning period from 1614.7 feet (March 31) to 1618.8 feet (May 31).

d. Summer Open Water Season 2019

Widespread rainfall across much of South Dakota kept runoff in the Garrison to Oahe reach above average during the summer months, ranging from 150 percent to over 600 percent of normal. Inflows during June, July, August and September, averaged 37,900 cfs (121 percent of average), 60,100 cfs (207 percent of average), 52,100 cfs (192 percent of average), and 53,700 cfs (234 percent of average), respectively. Oahe releases were above average during June (49,900 cfs; 186 percent of average), 55,500 cfs (178 percent of average) during July, 57,000 cfs (169 percent of average) during August, and 55,600 cfs (186 percent of average) during September. Above-average releases were required to evacuate all stored flood waters. During the June-September 4-month period, the pool steadily declined 3.7 feet to 1615.1 feet by the end of September.

e. Fall Open Water Season 2019

Inflows remained above average from October through December. Inflows in October were 54,300 cfs (264 percent of average), 47,900 cfs in November (227 percent of average) and 24,800 cfs in December (124 percent of average). Average monthly releases for October were 62,200 cfs (258 percent of average), 64,900 cfs (282 percent of average) during November and 31,800 cfs (154 percent of average) during December. The December 31 pool elevation was 1607.9 feet, 0.4 foot above the base of the Annual Flood Control and Multiple Use Zone.

f. Summary

The highest 2019 Oahe midnight reservoir level of 1618.8 feet occurred on May 31, 1.8 feet above the base of the 3-foot Exclusive Flood Control Zone. The 2019 minimum midnight pool elevation of 1605.8 feet occurred on January 30, 1.7 feet below the base of the Annual Flood Control and Multiple Use Zone. Oahe's 2019 average annual inflow was 43,200 cfs, 169 percent of average. Oahe's 2019 average annual release was 41,600 cfs, 172 percent of average. Big Bend's annual minimum midnight pool elevation of 1419.6 feet was recorded on January 25 and the annual maximum midnight pool elevation of 1421.5 feet was recorded on February 3.

5. Fort Randall Regulation – January to December 2019

a. General

Fort Randall, the fourth largest System reservoir, serves all authorized purposes. Fort Randall's primary functions are (1) to capture snow and localized rainfall runoff in the drainage area between Big Bend and Fort Randall dams, which are metered out at controlled release rates to meet the authorized purposes while reducing flood damages in the Fort Randall reach where several areas have homes and cabins in close proximity to the river; (2) to serve as a primary storage location along with the upstream projects for water accumulated in the System when System releases are reduced due to major downstream flood control regulation, thus helping to alleviate large pool increases in the very small Gavins Point reservoir; (3) to store the water necessary to increase winter hydropower energy by implementing an annual fall drawdown of the reservoir with a winter reservoir refilling that is unique to Fort Randall; and (4) to provide water needed to meet all authorized purposes, particularly navigation and downstream water supply, that draft storage during low-water years.

Table 11 lists the Fort Randall average monthly inflows and releases in cfs and the EOM pool elevation in feet for 2018 and 2019 as well as the historic averages since the System was first filled in 1967.

Table 11
Fort Randall – Inflows, Releases and Elevations

Month	Monthly Inflow (cfs)			Monthly Release (cfs)			EOM Elevation (feet)		
	2019	2018	1967-2018	2019	2018	1967-2018	2019	2018	1967-2018
January	25,000	28,100	22,100	20,700	18,600	15,300	1344.7	1347.8	1347.0
February	25,000	18,000	20,100	17,100	15,700	13,400	1350.7	1348.3	1351.8
March	35,200	26,500	21,700	11,600	16,000	15,800	1366.9*	1357.2	1356.0
April	40,800	31,600	23,900	46,000	30,000	21,400	1363.5	1358.6	1357.6
May	58,500*	37,300	25,100	47,800	37,200	25,200	1370.2*	1358.0	1357.3
June	53,800	39,600	29,800	65,000	33,500	28,600	1363.0	1362.0	1357.8
July	61,500	43,300	31,600	63,500	48,300	32,800	1361.3	1358.1	1356.6
August	64,100	53,500	34,100	65,300	54,100	35,100	1359.9	1357.2	1355.5
September	63,100	46,900	30,000	63,800	52,600	34,800	1359.1*	1352.6	1351.4
October	61,600*	45,400	23,500	75,000*	52,300	32,400	1348.2	1346.4	1343.4
November	63,300*	44,000	22,500	74,200*	53,000	29,000	1337.9	1337.4	1337.0
December	34,700	24,300	21,300	32,600*	21,400	17,300	1339.8	1340.5	1340.9
Annual	**48,900**	**36,500**	**25,500**	**48,600**	**36,100**	**25,100**			

*monthly maximum of record

b. Winter Season 2018-19

No reports of ice-affected flooding on the Missouri River below Fort Randall were recorded during the 2018-19 winter season. Fort Randall's average daily winter release ranged from 14,200 cfs to 22,500 cfs. The Fort Randall reservoir froze over on January 2 and was free of ice on April 7, which was a week earlier than the record of April 14, set in 1960.

c. Spring Open Water Season 2019

The Fort Randall pool elevation was 1350.7 feet on February 28. The pool level rose quickly after mid-March, ending the month at 1366.9 feet, 1.9 feet into its 10-foot Exclusive Flood Control Zone and 11.7 feet above its typical spring and summer pool level of 1355.2 feet. During the March 'bomb cyclone' event, inflows into Fort Randall and Gavins Point quickly increased as the rain-on-snow event melted much of the plains snowpack in those reaches. As Gavins Point inflows continued to increase, Fort Randall releases were reduced to 0 cfs on

March 13 and were held at 0 cfs for 2 days. Releases were increased on March 16 when Gavins Point inflows were forecast to decline. When inflows into Gavins Point did not decline as expected, Fort Randall releases were again decreased to 0 cfs on March 18 and held at 0 cfs through March 22. Releases were slowly increased on March 23 as Gavins Point inflows receded. These periods of 0 cfs and low releases, coupled with the highest March runoff in the Fort Randall reach, resulted in the rapid increase in the Fort Randall reservoir's elevation. The average March inflow of 35,200 cfs (162 percent of average) corresponded with average March releases of 11,600 cfs (73 percent of average). Releases were increased during April as inflows into Gavins Point declined and Gavins Point releases increased. Fort Randall average releases during April were 46,000 cfs (215 percent of average). Inflows remained above average for the month, averaging 40,800 cfs (171 percent of average). Above-average precipitation during May caused inflows to increase, which led to the reservoir to rise, ending the month at 1370.2 feet, 5.2 feet in its 10-foot Exclusive Flood Control Zone. Inflows averaged 58,500 cfs (233 percent of average) and releases averaged 47,800 cfs (190 percent of average).

d. Summer Open Water Season 2019

Inflows slowly declined during the summer, but still remained much above average. Despite below-average June precipitation in the Oahe to Fort Rndall reach, inflows averaged 53,800 cfs (181 percent of average). Releases averaged 65,000 cfs (227 percent of average) in June. Above-average precipitation during July, August and September across much of the South Dakota led to inflows remaining much above average for those months. Inflows averaged 61,500 cfs (195 percent of average), 64,100 cfs (188 percent of average), and 63,100 cfs (210 percent of average) for July, August and September, respectively. Releases remained above average in order to evacuate all stored flood waters. July releases averaged 63,500 cfs (194 percent of average). August and September releases averaged 65,300 cfs (186 percent of average) and 63,800 cfs (183 percent of average), respectively. During the summer, the reservoir declined 11.1 feet from 1370.2 feet at the end of May to 1359.1 feet by September 30.

A daily hydropower peaking pattern is typically established at Fort Randall during the T&E nesting season to provide flexibility to regulate over a range of releases while minimizing impacts to T&E species nesting below the project. A hydropower peaking pattern was not needed during this year's nesting season. Due to multiple unit outages throughout the summer and the higher-than-average upper Basin runoff resulting in higher-than-average releases from upstream System projects, releases from Fort Randall remained steady throughout the day as the flood tunnels were utilized.

e. Fall Open Water Season 2019

Normal regulation of Fort Randall includes the lowering of the pool level during the fall, reaching 1337.5 feet by the end of the navigation season, 17.5 feet below the normal summer level, to make room for capture of winter powerplant releases from the upper reservoirs. During a full navigation season, the pool is maintained above 1353.0 feet through the Labor Day weekend before starting the lowering of the pool. Inflows and releases were above average during the October-December period. On August 31, the pool level was 1359.9 feet, 4.7 feet above the typical pool elevation for that time of year. Heavy precipitation in mid-September caused the reservoir to rise more than 4 feet, to above 1363.0 feet. The high runoff delayed the start of the normal fall drawdown, with the reservoir ending September at elevation 1359.1 feet, a record high for that time of year. The Fort Randall reservoir steadily declined after mid-September and reached its lowest 2019 level of 1337.2 feet on November 29.

f. Summary

The highest 2019 Fort Randall midnight reservoir level of 1370.4 feet occurred on June 1, 5.4 feet into its 10-foot Exclusive Flood Control Zone. The lowest 2019 midnight reservoir level was 1337.2 feet on November 29. The average annual inflow was 48,900 cfs, 192 percent of average and the average annual release was 48,600 cfs, 194 percent of average.

6. Gavins Point Regulation – January to December 2019

a. General

Gavins Point, the most downstream of the System projects, is primarily used for flow re-regulating to smooth out the release fluctuations of the upper System projects to better serve downstream purposes. With a total storage of 428,000 acre-feet (AF), it provides only a small amount of flood control and is generally maintained in a narrow reservoir elevation band between 1205.0 and 1208.0 feet. Due to the limited storage, releases from Gavins Point must be backed up with releases from the upper System projects. Gavins Point is the key location in the initiation of release reductions for downstream flood control. Even though it has only a small amount of storage space for flood control, this volume is usually adequate to perform significant downstream flood control by coordinating Gavins Point release reductions with the upstream projects. Releases greater than the powerplant capacity, normally near 35,000 cfs, are passed through the spillway.

Table 12 lists the Gavins Point average monthly inflows and releases and the EOM pool elevation for 2018 and 2019 as well as the historic averages since the System was first filled in 1967.

b. Winter Season 2018-19

Gavins Point releases were above average the entire winter season. Releases were stepped down in late November and early December reaching the winter release rate of 20,000 cfs on December 11, 2018. December inflows were higher than expected. To ensure that all the 2018 flood waters were evacuated before the start of the 2019 runoff season, Gavins Point releases were slowly increased to 24,000 cfs from January 7-9. Releases were held at 24,000 cfs until February 2. By late January, all 2018 flood waters had been evacuated. Gavins Point releases were stepped down to 20,000 cfs on February 4 and then reduced to 18,000 cfs on February 14. Releases remained at 18,000 cfs until the end of February. The Gavins Point reservoir froze over on December 7, 2018 and was free of ice on April 1, which was about two weeks earlier than the record of April 16, set in 1962.

Table 12
Gavins Point – Inflows, Releases and Elevations

Month	Monthly Inflow (cfs)			Monthly Release (cfs)			EOM Elevation (feet)		
	2019	2018	1967-2018	2019	2018	1967-2018	2019	2018	1967-2018
January	22,700	21,500	17,500	23,100	20,700	17,300	1204.3	1206.9	1207.5
February	19,800	18,000	16,500	19,100	18,000	17,300	1205.8	1206.7	1205.8
March	30,500	21,500	19,700	30,600	21,500	19,700	1205.4	1206.6	1205.7
April	52,800*	34,200	25,200	52,500*	34,000	25,000	1206.1	1207.1	1205.9
May	58,100	39,200	28,800	57,400	39,500	28,500	1207.6	1205.8	1206.1
June	74,000	37,900	31,800	74,400	37,000	31,600	1206.3	1207.7	1206.2
July	70,300	49,700	34,900	70,000	49,600	34,500	1206.6	1207.4	1206.7
August	70,000	57,300	36,800	70,000	57,300	36,400	1206.4	1207.1	1207.2
September	72,200	56,500	36,800	72,100	56,100	36,400	1206.2	1207.5	1207.6
October	80,200*	56,400	34,700	80,000*	56,200	34,500	1206.7	1207.6	1207.8
November	78,900*	56,600	31,400	78,600*	56,700	31,400	1206.7	1206.8	1207.6
December	38,000*	25,300	19,400	37,700*	25,600	19,500	1207.2	1205.7	1207.3
Annual	**55,600**	**39,500**	**27,800**	**55,500**	**39,400**	**27,700**			

*monthly maximum of record

c. Winter River and Ice Conditions below Gavins Point

Freezing temperatures arrived in the Midwest in mid-December and resulted in the first report of floating ice on the Missouri River near Sioux City, IA on December 10, 2018. The lowest Missouri River stage at Sioux City recorded during the 2018-19 winter season was 7.2 feet on January 2, 1.4 feet lower than the previous year's low stage. This reduction in stage followed a night of below-zero temperatures with daytime highs in the low 30s (deg F). These conditions resulted in the formation of floating ice in the Missouri River.

Reports of floating ice were reported in the Sioux City area during three different periods: December 10-13, 2018, December 26-January 3 and January 18-March 11. Missouri River ice observers noted 5 to 85 percent floating ice with pan sizes ranging from 2 to 20 feet from Sioux City downstream to Waverly, MO. No reports of ice-affected flooding or lack of water supply on the Missouri River below Gavins Point were recorded during the 2018-19 winter season.

d. Spring Open Water Season 2019

The Gavins Point pool elevation was 1205.8 feet on February 28. The pool level rose rapidly in mid-March due to the record-high unregulated inflows into Gavins Point reservoir. A detailed description of the Gavins Point inflow and outflow to manage the very high March inflows into Fort Randall and Gavins Point is provided in Section II.C.1. During March, the average Gavins Point inflow was 30,500 cfs (155 percent of average), and the average outflow was 30,600 cfs

(155 percent of average). Despite the higher-than-average inflows, the end-of-March pool elevation was 1205.4 feet, 0.3 foot below the end-of-March average. The Gavins Point pool reached a record-high peak elevation of 1212.3 feet, 2.3 feet into the surcharge zone, on March 15, and a peak daily inflow of 125,000 cfs on March 14. A peak average daily release of 90,500 cfs was made on March 15.

From April 1-8, the Gavins Point release was increased from 39,000 cfs to a steady release of 55,000 cfs. The average April inflow was 52,800 cfs, and the average April outflow was 52,500 cfs, both about two times average. The end-of-April pool elevation was 1206.1 feet, 0.2 foot above average.

Due to the record high May precipitation in the states of Nebraska, Kansas and Missouri, tributary and Missouri River flows remained in moderate to major flood stage throughout May. As the lower Missouri River flood peaks crested, Gavins Point releases were increased to 60,000 cfs on May 23, then stepped up to 70,000 cfs by May 29 in order to continue evacuating stored flood water in the System. As a result of the increased inflows from Fort Randall, the average May Gavins Point inflow was 58,100 cfs, about two times average. The average May Gavins Point release was 57,400 cfs, about two times the average May release. The end-of-May pool elevation was 1207.6 feet, 1.5 feet above the average end-of-May pool elevation.

e. Summer Open Water Season 2019

Inflows in the lower four System reservoirs – Oahe, Big Bend, Fort Randall and Gavins Point – were significantly higher than average during June-August. As a result, inflows and outflows continued to be about two times the average June-August rates. The Gavins Point June inflow and outflow were 74,000 cfs and 74,400 cfs, respectively, compared to the averages of 31,600 cfs and 31,800 cfs. The end-of-June pool elevation was 1206.3 feet, which is about average. During July and August, the Gavins Point inflow and outflow were about 70,000 cfs. The end-of-July pool elevation was 1206.6 feet, which is about average, while the end-of-August pool elevation was 1206.4 feet, 0.8 foot below average.

f. Fall Open Water Season 2019

Due to very heavy precipitation in early September in eastern South Dakota, tributary inflows below Gavins Point were extremely high. The Gavins Point release was reduced from 70,000 cfs to 60,000 cfs from September 15-18 to provide some downstream flood relief in the locations where Missouri River levee system restoration was ongoing. From September 18-21, the Gavins Point release was stepped up to 80,000 cfs, resulting in an average September release of 72,100 cfs, about two times the average September release. The end-of-September pool elevation was 1206.2 feet, 1.4 feet below the average end-of-September pool elevation.

Inflows and releases were above average during the October-December period. The Gavins Point release averaged 80,000 cfs in October, 78,600 cfs in November and 37,700 cfs in December, more than two times the average October and November releases, and about two times the average December release. October-December end-of-month pool elevations were all below average. The Gavins Point release was reduced to 27,000 cfs by December 15, and held at 27,000 cfs through the end of the calendar year.

g. Summary

The highest Gavins Point midnight reservoir level in 2019 was 1211.9 feet, reached on March 16, 0.4 foot lower than the aforementioned record. The lowest midnight reservoir level in 2019 was 1204.2 feet, reached on February 1. The average annual inflow to Gavins Point was 55,600 cfs, 27,800 cfs above average. The average annual Gavins Point release was 55,500 cfs, 27,700 cfs above average.

D. Non-Routine Regulation and Other Items Pertaining to System Regulation

Numerous regulation activities are performed each year that, although at one time may have been considered special, are now considered routine. These include release restrictions from a particular project for a period of time to permit hydrographic surveys, to facilitate limited construction within or adjacent to the downstream channel, and to pattern releases to facilitate measurements of downstream discharges and water surface profiles. Events that occurred recently with a connection to regulation activities are discussed in the following paragraphs.

On March 5, 2014, a takings claim was filed in the United States Court of Federal Claims by approximately 200 plaintiffs against the Corps for alleged flooding along the Missouri River from 2007 to 2013 (Ideker Farms, Inc., et al. v. U.S.). The claim was amended on October 15, 2014 adding approximately 170 new plaintiffs and CY 2014 flooding claims. The plaintiffs allege that the Corps, in the operation of the Missouri River Mainstem Reservoir System since the Master Manual was updated in 2004 and 2006, in conjunction with habitat creation efforts to comply with the 2003 Amended USFWS Biological Opinion, has caused an increase in flooding along the Missouri River. Plaintiffs contend, therefore, that through these actions the U.S. government has "taken" their property, in violation of the Fifth Amendment of the U.S. Constitution, for which they are entitled just compensation. In February 2019 the judge issued an opinion for Phase I of the trial that examined the claims of 44 representative plaintiffs and Phase II of the trial is scheduled for June 2020.

In mid-May, Kansas City District requested a deviation from the MRBWM office to increase the flow criteria for flood control releases on the Missouri River at Waverly, MO. The deviation was approved and increased the Phase I flow criteria at Waverly from 90,000 cfs to 110,000 cfs and the Phase II flow criteria from 130,000 cfs to 160,000 cfs. The deviation was requested to reduce the likelihood of exceeding designated flood control storage in the four lower Kansas River basin reservoirs: Clinton, Perry, Tuttle Creek and Milford. In late May, after continued rains and wet basin conditions, Kansas City District requested a deviation from the MRBWM office from all tributary and Missouri River flood control targets downstream of the four Kansas River basin projects. At this time, the four projects were either in surcharge operations or nearing surcharge operations, and the deviation was approved. In mid-June the original deviation was modified so that the Phase II flow criteria for the Missouri River at Waverly was raised from 160,000 cfs to 180,000 cfs. In late August an additional deviation request was made to raise the Phase I Missouri River at Waverly flow criteria to 140,000 cfs. The deviation was approved by the MRBWM office to allow for evacuation of stored flood water in the Kansas River projects prior to the start of the 2020 runoff season. In June, the Kansas City District also requested a deviation to temporarily suspend criteria for Stockton and Truman so that emergency spillway tainter gate repairs could be made at Stockton. The deviation was approved by the MRBWM office and allowed for stabilization of the Stockton reservoir elevation to facilitate construction activities.

In late May, the MRBWM office requested that the Omaha District Water Control and Water Quality Section and the U.S. Bureau of Reclamation (USBR) assess whether releases from the Section 7 USBR projects could be reduced to help minimize inflows into Fort Peck and Garrison. In early June, with acknowledgement this regulation would likely lead to storing water in the flood control zones, releases were reduced at Boysen, Yellowtail, Canyon Ferry and Tiber. Releases were adjusted with a target of using approximately 25 to 40 percent of the flood storage in these projects. More detailed information can be found in the Omaha District Water Control and Water Quality Section's Annual Report on Tributary Reservoir Regulation Activities.

E. Reservoir Elevations and Storage

Reservoir elevations and storage levels of the System reservoirs at the end of July 2019 are presented in ***Table 13*** and the same information for the end of December 2019 is presented as ***Table 14***. The upper three reservoirs, Fort Peck, Garrison and Oahe, contain approximately 90 percent of the total System storage and pool levels can vary, especially during high inflow (flood) or low inflow (drought) periods. The lower three reservoirs are generally regulated in such a manner that their pool levels do not fluctuate much from year to year. For the upper three reservoirs, the 12-month change columns for the end of July indicate that Fort Peck, Garrison and Oahe were similar to the previous year, ranging from -0.3 to 0.9 foot different. By the end of December, Fort Peck, Garrison and Oahe remained above the base of their respective Annual Flood Control and Multiple Use Zones, ranging from 0.4 to 3.0 feet above their bases, respectively.

Table 13
Reservoir Levels and Storages – July 31, 2019

Project	Reservoir Elevation		Reservoir Storage in 1,000 AF		
	Elevation (feet)	12-Month Change (feet)	Total	Above Min. Level*	12-Month Change
Fort Peck	2246.2	+0.1	17,537	13,449	+19
Garrison	1851.6	+0.9	22,569	17,775	+341
Oahe	1616.9	-0.3	21,868	16,553	-70
Big Bend	1420.7	-0.1	1,674	43	-13
Fort Randall	1361.3	+3.2	3,966	2,497	+290
Gavins Point	1206.6	-0.8	342	47	-17

Table 14
Reservoir Levels and Storages – December 31, 2019

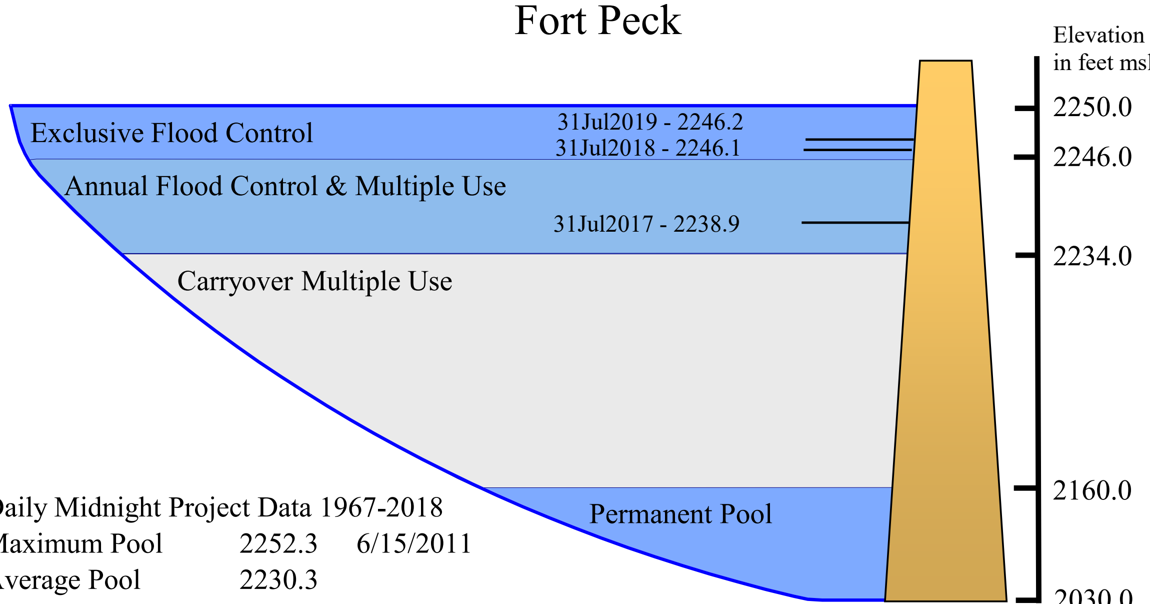
Project	Reservoir Elevation		Reservoir Storage in 1,000 AF		
	Elevation (feet)	12-Month Change (feet)	Total	Above Min. Level*	12-Month Change
Fort Peck	2237.0	-0.2	15,442	11,354	-43
Garrison	1839.2	-0.4	18,259	13,465	-152
Oahe	1607.9	+0.7	18,785	13,470	+218
Big Bend	1421.5	+0.8	1,680	49	+9
Fort Randall	1339.8	-0.7	2,320	851	-41
Gavins Point	1207.2	+1.5	356	61	+36

*Net usable storage above minimum reservoir levels established for power, recreation, irrigation diversions and other purposes.

Figure 28A and ***Figure 28B*** show the end-of-July pool elevations for Fort Peck, Garrison and Oahe plus total System end-of-July storage for 2017 through 2019. Individual tables with the historic maximum, average and minimum pool elevations for each reservoir are also shown on ***Figure 28A*** and ***Figure 28B.***

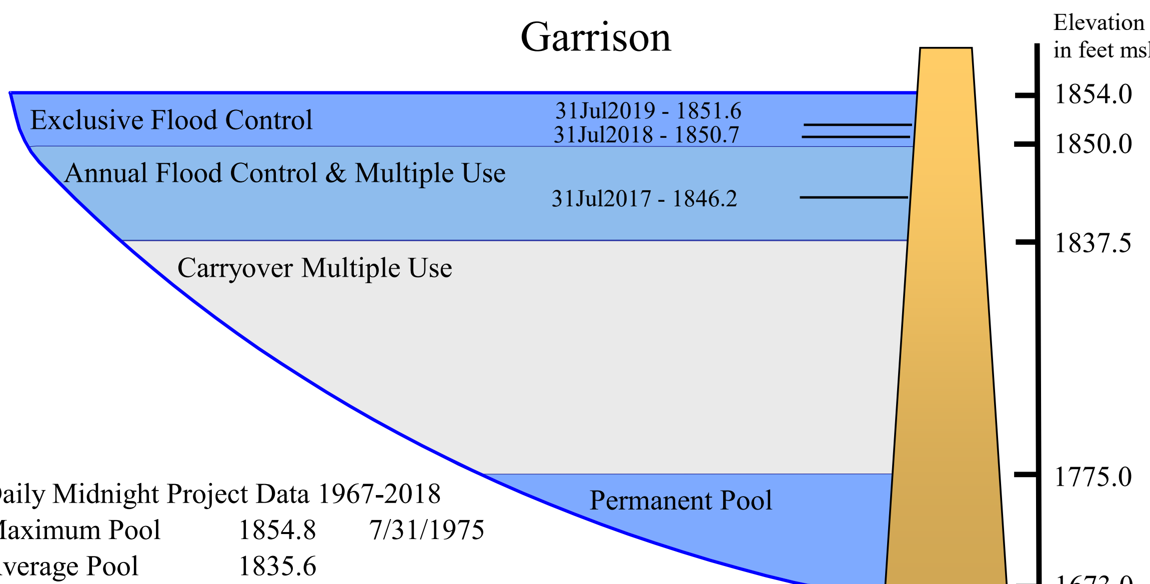
Missouri River System Reservoirs
End-of-July Pool Elevations and Total System Storage

Fort Peck



Daily Midnight Project Data 1967-2018		
Maximum Pool	2252.3	6/15/2011
Average Pool	2230.3	
Minimum Pool	2196.2	3/4/2007
Maximum for 2019	2246.8	7/10/2019
Minimum for 2019	2234.3	3/3/2019

Garrison

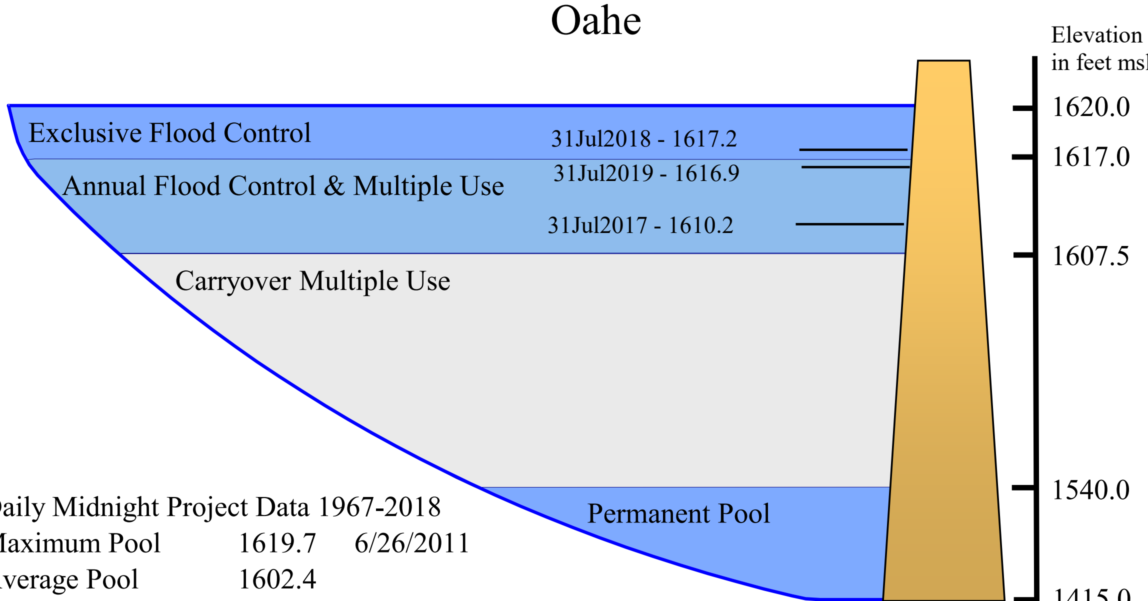


Daily Midnight Project Data 1967-2018		
Maximum Pool	1854.8	7/31/1975
Average Pool	1835.6	
Minimum Pool	1805.8	5/12/2005
Maximum for 2019	1852.5	7/9/2019
Minimum for 2019	1836.9	3/15/2019

Figure 28A. End-of-July pool elevations for Fort Peck and Garrison.

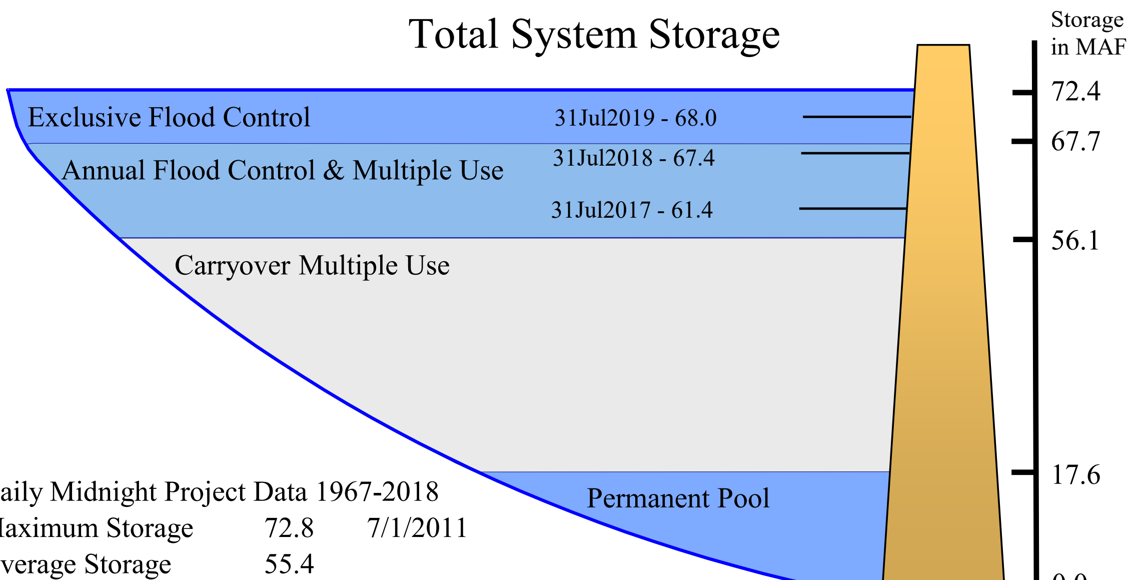
Missouri River System Reservoirs
End-of-July Pool Elevations and Total System Storage

Oahe



Daily Midnight Project Data 1967-2018		
Maximum Pool	1619.7	6/26/2011
Average Pool	1602.4	
Minimum Pool	1570.2	8/31/2006
Maximum for 2019	1618.8	5/31/2019
Minimum for 2019	1605.8	1/30/2019

Total System Storage



Daily Midnight Project Data 1967-2018		
Maximum Storage	72.8	7/1/2011
Average Storage	55.4	
Minimum Storage	33.9	2/8/2007
Maximum for 2019	68.5	7/20/2019
Minimum for 2019	56.0	2/15/2019

Figure 28B. End-of-July pool elevations for Oahe and total System storage.

F. <u>Summary of Results</u>

1. Flood Control

Upper basin runoff during 2019 was 60.9 MAF, the second highest runoff in 122 years of record-keeping (1898-2019). Per Plate VI-1 of the Master Manual, the service level was adjusted several times from a "full" service level of 35,000 cfs to an "expanded" service level during the spring to manage the above-average runoff. The service level determination is based on 1) current System storage, 2) current storage in 10 USBR reservoirs upstream of Oahe, and 3) forecasted annual runoff above Gavins Point. Service level adjustments were made four times during the spring:

March 18:	service level increased from 35,000 cfs to 45,000 cfs
April 1:	service level increased from 45,000 cfs to 50,000 cfs
May 1:	service level increased from 50,000 cfs to 55,000 cfs
June 1:	service level increased from 55,000 cfs to 70,000 cfs

The increase in service level does not mean that releases from the System projects are increased accordingly. Rather, the increase in service level increases the flow targets at Omaha, Nebraska City and Kansas City.

Operation of federal projects during significant runoff events in the Omaha and Kansas City Districts resulted in flood damage reduction. As shown on ***Figure 19A*** through ***Figure 19E***, flows at locations downstream of the mainstem projects were significantly reduced due to operation of the mainstem reservoirs. These figures show the 2019 regulated (actual experienced) and unregulated (with no System reservoirs and tributary reservoirs) Missouri River flows for various reaches.

The total flood damages prevented by all Corps-controlled reservoir projects, levees and emergency operations in the Missouri River Basin during 2019 were estimated to be about $12.26 billion ($3.63 billion Omaha District; $8.63 billion Kansas City District). Flood damages prevented by the System reservoirs during 2019 were estimated to be $8.6 billion. This amount includes $624 million of damages prevented on the Mississippi River by System projects, as calculated by the St. Louis District. This amount is not included in either the NWK or NWO Flood Damage Reduction database. The System flood damages prevented indexed to the September 2019 price level is illustrated in ***Figure 29A.*** Since 1938, the total flood control damages prevented by the System were $75.7 billion, an annual average of about $920 million, indexed to September 2019 price levels. The total un-indexed flood damages prevented at the original price levels is $46.0 billion, an annual average of about $560 million (see ***Figure 29B***). The bulk of the damages prevented occurred in 2018 and 2019, during the 6-year period from 1993 to 1999, and during the 4-year period from 2008 to 2011. For comparison purposes, ***Figure 29A*** and ***Figure 29B*** include the construction cost of the dams. Indexed to 2019 price levels, the dams cost approximately $29.0 billion, whereas the original un-indexed cost was $1.2 billion.

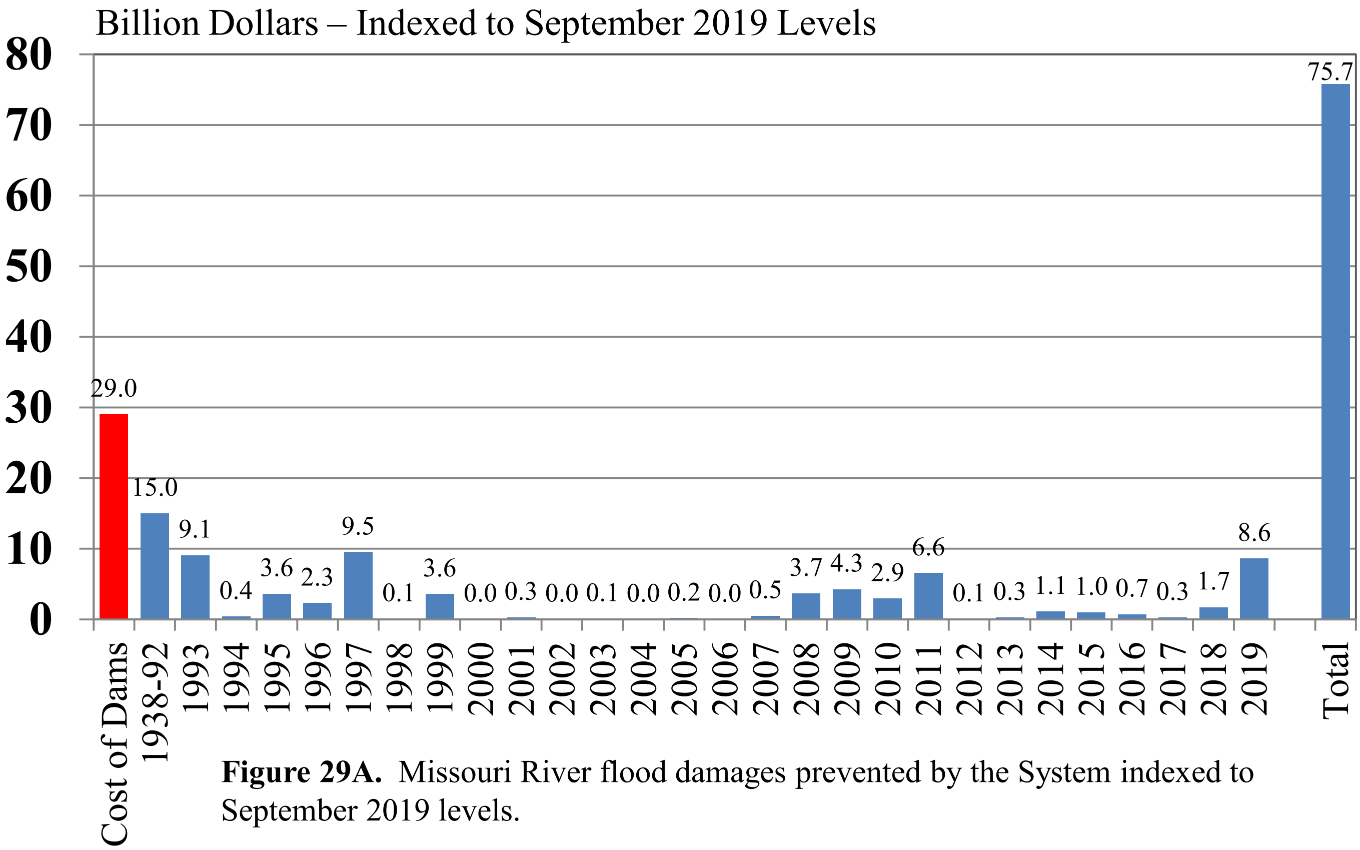


Figure 29A. Missouri River flood damages prevented by the System indexed to September 2019 levels.

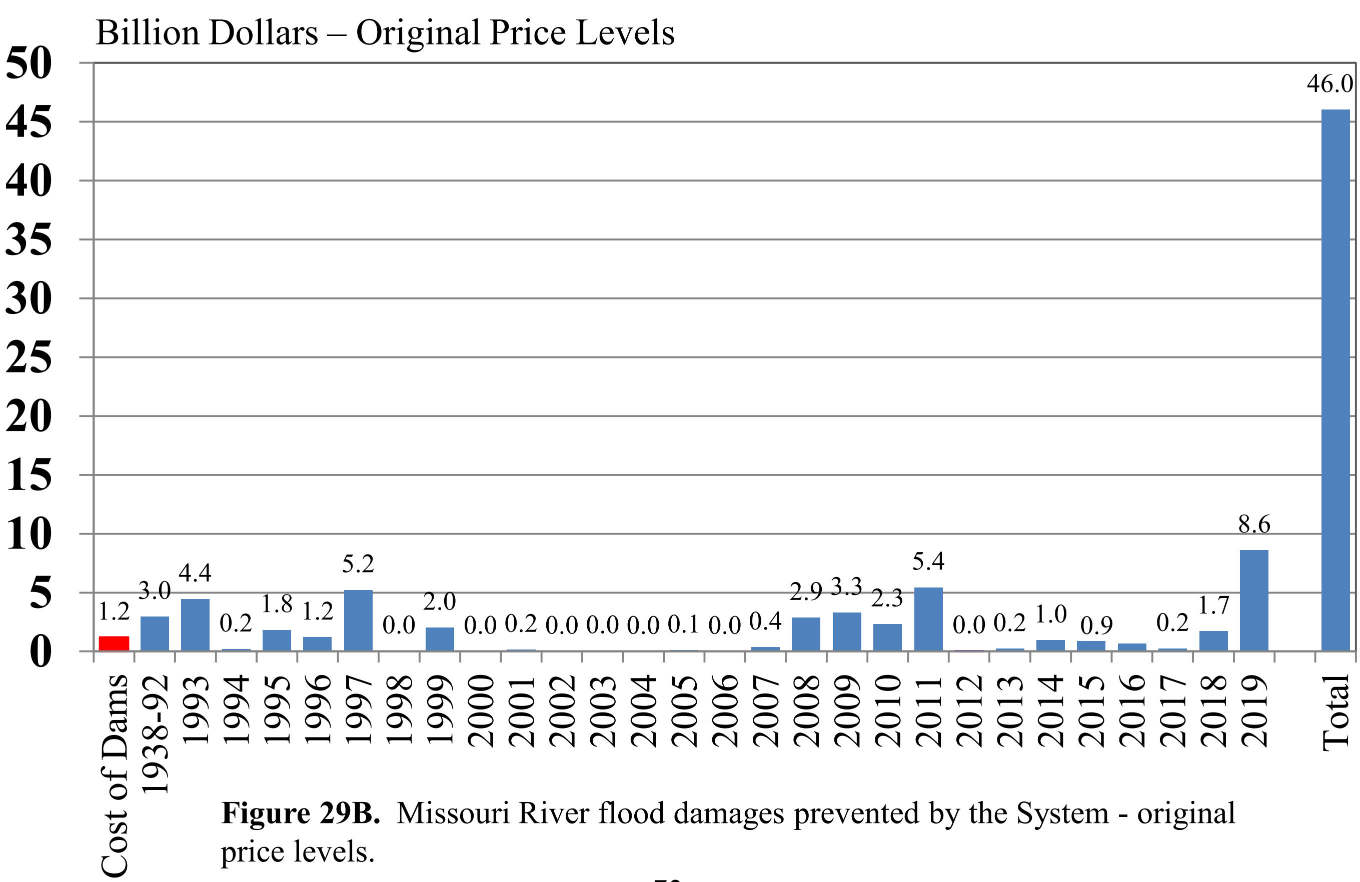


Figure 29B. Missouri River flood damages prevented by the System - original price levels.

2. Irrigation

Federally-developed irrigation projects are not being served directly from the System reservoirs. The reservoirs, however, are being utilized by numerous private irrigators as well as federally-financed projects that take water from the Missouri River. About 900 private irrigators pump directly from the reservoirs or river reaches.

3. Water Supply

Problems at municipal and industrial (M&I) intakes located in the river reaches and System reservoirs are related primarily to intake or river access problems rather than inadequate water supply. Intake owners today are generally better prepared to handle periods of low water with adjustments to intakes or regulation procedures. Some of these adjustments involve using warm water to keep ice formation from building up on intake screens; installing new pumps; lowering intakes; installing sediment redirection vanes and ice deflectors; obtaining, or arranging to obtain, alternate sources of water; and cleaning screens more thoroughly and frequently. While these remedial actions are sometimes expensive to install and operate, they significantly improved the ability of the intakes to operate at lower river stages and reservoir levels.

The September 1 storage check indicated a winter release of no less than 17,000 cfs. In order to continue evacuation of stored flood water, Gavins Point winter releases were above 17,000 cfs, which did not result in any intake access issues.

4. Water Quality Control

a. Overview

During 2019 the Omaha District (NWO) conducted fixed-station ambient water quality monitoring at the mainstem reservoirs and on the lower Missouri River. Water quality conditions of the water discharged through each of the mainstem dams was continuously monitored. More detailed water quality monitoring information is available in the NWO water quality reports on the NWO website at
http://www.nwo.usace.army.mil/Missions/WaterInformation/WaterQuality/Reports.aspx

NWO has identified seven priority water quality issues that have relevance to the mainstem reservoirs. These identified priority issues are:

1. Determine how regulation of the mainstem dams and reservoirs affect water quality in the impounded reservoirs. Utilize the CE-QUAL-W2 hydrodynamic and water quality model to facilitate this effort.
2. Evaluate how eutrophication is progressing in the mainstem reservoirs, especially regarding the expansion of hypoxic conditions in the hypolimnion during summer stratification.
3. Determine how flows released from mainstem reservoirs affect water quality in the downstream Missouri River. Utilize the HEC-RAS water quality model to facilitate this effort.

4. Determine how current water quality conditions in the Missouri River (e.g., water temperature, turbidity) may be affecting pallid sturgeon populations in the Missouri River.
5. Provide water quality information to support decision making (e.g., Corps reservoir regulation elements for effective surface water quality and aquatic habitat management, Tribes and States in the development of their Section 303(d) lists and development and implementation of total maximum daily loads (TMDLs) at NWO tributary projects).
6. Identify existing and potential surface water quality problems at NWO tributary projects and develop and implement appropriate solutions.
7. Evaluate surface water quality conditions and trends at NWO tributary projects.

Table 15 provides a summary of water quality issues and concerns at each of the mainstem reservoirs and the lower Missouri River based on NWO monitoring and a review of current state-integrated water quality reports.

b. Occurrence of "Two-Story" Fisheries at Mainstem Reservoirs

The Fort Peck, Garrison, and Oahe reservoirs maintain "two-story" fisheries that are comprised of warmwater and coldwater species. The ability of the 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 fish species inhabit the hypolimnion. Certain coldwater fish species are used extensively as forage by both coldwater and warmwater predator fish species in the reservoirs. Coldwater forage species that inhabit the reservoirs include the rainbow smelt (*Osmerus mordax*) and lake herring/lake cisco (*Coregonus artedi*). Maintaining healthy populations of these coldwater forage fish is important to maintaining both the coldwater and warmwater recreational fisheries in the three reservoirs.

c. Bottom-Withdrawal Reservoirs

Bottom-withdrawal reservoirs have outlet structures located near the deepest part of the reservoir. During the summer thermal-stratification period, the bottom withdrawal releases cold water from the deep portion of the reservoir that may be hypoxic during latter periods of stratification. Hypoxic conditions in the hypolimnion can result in the release of water with low dissolved oxygen and high levels of nutrients and other constituents. Bottom outlets can cause density interflows or underflows through the reservoir and generally provide little or no direct control over the quality of the water released through the bottom withdrawal. Garrison and Fort Randall are bottom withdrawal projects with both their power and flood tunnels drawing water from the bottom of the impounded reservoirs. Fort Peck Dam has a near-bottom withdrawal (i.e., 60 feet above the reservoir bottom) for the power and flood tunnels. The power tunnels at Oahe Dam draw water at a mid-depth elevation (i.e., 114 feet above the reservoir bottom); however, the flood tunnels draw water from the bottom of the reservoir. The Big Bend and Gavins Point powerplants both draw water from the bottom of the reservoir; however, these are shallower, re-regulation projects and water drawn into the powerplants is usually fairly well mixed through the reservoir water column.

Table 15
Water Quality Issues and Concerns

Project	Total Maximum Daily Load (TMDL) Considerations*				Fish Consumption Advisories		Other Potential Water Quality Concerns
	On 303(d) List	Impaired Uses	Pollutant/Stressor	TMDL Completed	Advisory in Effect	Identified Contamination	
Fort Peck • Fort Peck Lake	Yes (MT)	Drinking Water Supply	Lead Mercury	No	Yes	Mercury	---
		Recreation	Aquatic plants - native	NA**			
• Missouri River, Fort Peck Dam to the Milk River	Yes (MT)	Aquatic Life Coldwater Fishery	Water temperature	No	No	---	---
			Degraded riparian vegetation Other flow regime alterations	NA**			
• Missouri River, Milk River to the Poplar River	Yes (MT)	Aquatic Life Warmwater Fishery	Water temperature	No	No	---	---
			Degraded riparian vegetation Other flow regime alterations	NA**			
• Missouri River, Poplar River to North Dakota	Yes (MT)	Aquatic Life Warmwater Fishery	Water temperature	No	No	---	---
			Other flow regime alterations	NA**			
Garrison • Lake Sakakawea	Yes (ND)***	Fish Consumption	Methyl-mercury	No	Yes	Mercury	Coldwater fishery during drought conditions. Tailwater dissolved oxygen levels.
• Missouri River, Garrison Dam to Lake Oahe	No	---	---	---	Yes	Mercury	Low dissolved oxygen in Garrison Dam tailwaters (associated with late summer hypolimnetic lake withdrawals).
Oahe • Lake Oahe	Yes (SD)	Coldwater Permanent Fish Life Fish/Wildlife Propagation Recreation Stock Watering	Mercury in Fish Tissue	Yes	Yes	Mercury	Fish consumption advisory issued by North Dakota and Cheyenne River Sioux Tribe for Lake Oahe. TMDL completed by South Dakota for Mercury in Fish Tissue.
Big Bend • Lake Sharpe	Yes	Coldwater Permanent Fish Life	Temperature Dissolved Oxygen	No	No	---	TMDL completed for sediment. A nonpoint source management project is being implemented in the Bad River watershed. Draft Fishery Reclassification Report (Warmwater) is under review at EPA.
Fort Randall • Lake Francis Case	No	---	---	---	No	---	Low dissolved oxygen in Fort Randall Dam tailwaters (associated with late summer hypolimnetic reservoir withdrawals).
• Missouri River, Fort Randall Dam to Lewis and Clark Lake	Yes (NE)	Warmwater Aquatic Life (NE)	Mercury in Fish Tissue (NE)	No	Yes (NE)	Mercury	Fish consumption assessment completed by Nebraska
Gavins Point • Lewis and Clark Lake	Yes (NE)	Aquatic Life (NE)	*E. coli* (NE) Chlorophyll-a (NE)	No	No	---	Sedimentation. Emergent aquatic vegetation.
• Missouri River, Gavins Point Dam to the Big Sioux River	Yes (NE)	Recreation Drinking Water Supply	*E. coli* Sulfate	No	No	---	Reduced suspended sediment and turbidity impacts to pallid sturgeon. Assimilative capacity and flow reduction.
• Missouri River, Big Sioux River to Platte River	Yes (NE)	Recreation Drinking Water Supply	*E. coli* Sulfate	No	No	---	Reduced suspended sediment and turbidity impacts to pallid sturgeon. Assimilative capacity and flow reduction.
• Missouri River, Platte River (NE) to NE-KS Stateline	Yes (MO, NE)	Recreation Aquatic Life	*E. coli* Mercury in Fish Tissue	Yes (NE)	Yes (NE)	---	Reduced suspended sediment and turbidity impacts to pallid sturgeon. Assimilative capacity and flow reduction.

* Information taken from published state integrated water quality reports and impaired waters 303(d) listings as of January 1, 2020.
** Impairment identified in Montana's integrated report, but not on 303(d) list for development of a TMDL.
*** Delisted in 2010 for impairment of the designated use "Fish and other Aquatic Biota" (warm water temperature and low dissolved oxygen) when Lake Sakakawea pool elevations recovered from drought conditions.

d. Fort Peck Reservoir

Fort Peck reservoir is not assigned a coldwater fishery use by the State of Montana in their water quality standards. However, the reservoir supports a stocked put-grow-take salmon fishery and a naturally reproducing lake trout (*Salvelinus namaycush*) and lake cisco fishery; all are considered coldwater species. Since a coldwater fishery is currently supported in Fort Peck reservoir, it is seemingly an existing use to be protected pursuant to the anti-degradation provisions of the Federal Clean Water Act (40 CFR 131.3).

Dissolved oxygen concentrations below Montana's 5 mg/L, 7-day mean minimum water quality standard were monitored at the Fort Peck powerplant for the first time in 2012. A special water quality study was conducted by NWO in 2012 to evaluate the situation. When monitored on September 25, 2012 the area immediately downstream of the dam to just beyond the energy dissipation structures was below 5 mg/L dissolved oxygen, while the area from just downstream of the energy dissipation structures through the dredge cuts area was just above 5 mg/L. During 2014-2019 dissolved oxygen in the water discharged through the Fort Peck powerplant has remained above the 5 mg/L minimum water quality standard with minimum instantaneous values 6.1 mg/L (2014), 5.9 mg/L (2015), 6.5 mg/L (2016), 6.4 mg/L (2017), 9.9 mg/L (2018), and 6.2 mg/L (2019). The situation will continue to be evaluated to determine if corrective measures to meet State water quality standards may be needed.

e. Garrison Reservoir

The State of North Dakota's water quality standards classifies Garrison reservoir as a coldwater fishery. To protect the coldwater fishery use, the State has promulgated the following water quality standards for Garrison reservoir: a water temperature criterion of ≤ 59 deg F (or 15 degrees C), a dissolved oxygen criterion of ≥ 5 mg/L, and a minimum reservoir volume of 500,000 AF (0.5 MAF) that meet these criteria.

Water temperature and dissolved oxygen depth profiles that were measured during water quality monitoring conducted at Garrison reservoir over the 5-year period 2015 through 2019 were used to estimate the volume of water in the reservoir that meets the coldwater fishery habitat conditions defined by the State of North Dakota. ***Plate 4*** shows estimated reservoir and coldwater fishery habitat volumes, by year, for 2015 through 2019. Water quality monitoring in 2019 indicates that North Dakota's 0.5 MAF minimum water quality standards criterion for coldwater fishery habitat was seemingly met; however, temporal variability in data collected at Garrison does allow for some uncertainty in this measurement.

To better assess the occurrence and support of coldwater fishery habitat in Garrison reservoir, NWO is currently updating their CE-QUAL-W2 hydrodynamic and water quality modeling of the reservoir. A comprehensive water quality report of Garrison reservoir, including application of the CE-QUAL-W2 model and how the Corps' regulation of the project influence water quality conditions can be found at the Omaha District Water Control and Water Quality Section's website.

Dissolved oxygen concentrations below North Dakota's 5 mg/L water quality standard have been monitored in late summer at the Garrison powerplant. To date, there is no evidence of current or past fish kills in the Garrison tailwaters. A Special Water Quality Study of the situation is being considered, and the situation will continued to be evaluated to determine if corrective measures to meet State water quality standards may be needed.

f. Oahe Reservoir

South Dakota's water quality standards protect Oahe for a Coldwater Permanent Fish Life Propagation (CPFLP) use (i.e., coldwater fishery). As such, a water temperature criterion of ≤ 65 deg F (18.3 degrees C) and a dissolved oxygen criterion of ≥ 6 mg/L have been promulgated by South Dakota to protect the coldwater fishery of Oahe.

The occurrence of coldwater fishery habitat (i.e., water temperature ≤ 18.3 degrees C and dissolved oxygen ≥ 6 mg/L) in Oahe was estimated from water quality monitoring conducted over the 5-year period 2015 through 2019. ***Plate 5*** shows estimated reservoir and coldwater fishery habitat volumes, by year, for 2015 through 2019. At least 2 MAF of coldwater fishery habitat was present in Oahe for all years.

g. Big Bend Reservoir

The State of South Dakota classifies Big Bend for a CPFLP use and currently lists the designated coldwater fishery as impaired due to warmwater temperatures and low dissolved oxygen levels, and targets the reservoir for development of a TMDL in the near future. South Dakota has pursued reclassification of the Big Bend reservoir from a coldwater fishery to a warmwater fishery based on a use attainability assessment. Currently, the draft reclassification report is under review by the EPA. Natural summer water temperatures of the Oahe powerplant discharge, especially during lower pool levels, do not meet the temperature requirements for a CPFLP use in Big Bend.

h. Fort Randall Reservoir

Hypolimnetic water is passed through Fort Randall Dam during power production in the summer and dissolved oxygen levels in the Fort Randall tailwaters fall below South Dakota's water quality standards' minimum dissolved oxygen criterion of 5 mg/L for protection of the designated Warmwater Permanent Fish Life Propagation (WPFLP) use. The low dissolved oxygen levels in the tailwaters are not impairing the designated WPFLP use as regions of refugia exist in the impacted area, and there is no evidence of current or past summer fish kills in the tailwaters attributable to low dissolved oxygen levels. If warranted, low dissolved oxygen levels in the Fort Randall tailwaters, during periods of hypolimnetic releases, could be mitigated by spilling surface water with higher dissolved oxygen concentrations down the spillway. The situation will continue to be evaluated to determine if corrective measures to meet South Dakota's water quality standards may be needed.

i. Gavins Point Reservoir

Gavins Point reservoir is currently identified as impaired by the State of Nebraska in their 303(d) listing of impaired waters. Nebraska identifies impairment to the use of aquatic life due to high chlorophyll-α levels. Of the six mainstem reservoirs, Gavins Point is exhibiting the most impact from nutrient loading and eutrophication. Eutrophication concerns at Gavins Point will likely increase as the reservoir continues to age. The current estimated volume loss of the Carryover Multiple Use Pool Zone (30 percent) in Gavins Point exceeds the State of Nebraska's criterion (25 percent volume loss) for listing the reservoir as impaired for aesthetics. Gavins Point is not currently listed as impaired for sedimentation by the State of Nebraska.

5. Navigation

a. Barge Traffic

System releases provide navigation flow support in the Missouri River Bank Stabilization and Navigation Project (BSNP). Minimum navigation flow support, which is 6,000 cfs below full service, provides flow to ensure a minimum 8-foot channel depth. Full service navigation flow support provides flow to ensure a minimum 9-foot deep and 300-foot wide channel in the BSNP. Navigation flow support for the first half of the season is determined by the March 15 System storage check. Navigation flow support for the second half of the season, as well as season length, is determined by the July 1 System storage check. System releases are set to meet navigation target flows at four Missouri River locations – Sioux City, Omaha, Nebraska City and Kansas City.

Based on the March 15 System storage of 56.6 MAF, navigation flow support was at a full service level for the first half of the navigation season. With above-average runoff into Oahe Fort Randall and Gavins Point reservoirs, March releases from Gavins Point were above full service levels to lessen the time that those projects had water stored in the Fort Randall and Gavins Point Exclusive Flood Control zones and to keep the Oahe reservoir from entering into its Exclusive Flood Control Zone.

On January 9, 2019 the year's first commercial load entered the Missouri River at St. Louis, MO. The Corps' Missouri River Project Office at Napoleon, MO recorded 22 loads and 24 empties on and off the Missouri River before April 1, when navigation flow supports begins at the mouth. The last commercial tow left the Missouri River on December 16.

b. Tonnage

Table 16 shows the final Missouri River tonnage data for 2014-18 compiled by the Waterborne Commerce Statistics Center (WCSC). Final navigation data is generally one year behind the summary report reporting year because the WCSC needs an extended period of time to compile the data. The 2018 total of 4.534 million tons includes 3.668 million tons for sand and gravel, 0.110 million tons for waterways materials, and 0.757 million tons for long-haul commercial tonnage. In 2018, the total tonnage decreased by 0.423 million tons compared to 2017. The long-haul tonnage of 0.757 million tons is an increase of 0.02 million tons from 2017.

The largest long-haul commercial tonnage, excluding sand, gravel and waterway material, occurred in 1977 at 3.34 million tons. ***Figure 30A*** shows total navigation tonnage on the Missouri River. ***Figure 30B*** shows the long-haul commercial navigation tonnage not including sand, gravel and waterway materials. The long-haul commercial tonnage in 2019 is estimated at 0.479 million tons, based on the WCSC current data estimates. ***Figure 31A*** shows the navigation tonnage value of the commodities since 1960, using 2019 present-worth computations. ***Figure 31B*** shows the navigation tonnage value of long-haul commercial commodities since 1960. The 2019 tonnages and tonnage values shown in ***Figure 30A, Figure 30B, Figure 31A*** and ***Figure 31B*** are estimates and will change once final WCSC tabulations are available.

Navigation season target flows for past years are presented in ***Table 17***. ***Table 18*** shows the scheduled lengths of past System-supported navigation seasons, with total tonnage and ton-miles for each year. ***Figure 32A*** and ***Figure 32B*** presents flows at the four navigation flow-target locations. There was no navigation support from the Corps' Kansas Basin projects in 2019.

The 2019 navigation season experienced portions of the lower Missouri River being closed to navigation for a total of 45 days. The dates and reaches of the lower Missouri River closures are shown in ***Table 19***. These closures were made by the U.S. Coast Guard (USCG) in coordination with the Corps and State officials following the USCG's Waterways Action Plan (WAP). The WAP outlines the stages and river conditions and what navigation actions occur in response to high flows on the lower Missouri River to maintain safe river transportation.

Table 16
Missouri River Tonnage by Commodity (1,000 Tons)

Commodity Classification Group	**2014**	**2015**	**2016**	**2017**	**2018**
Farm Products	**53**	**50**	**231**	**330**	**244**
Corn	*9*	*34*	*97*	*168*	*109*
Wheat	*0*	*3*	*2*	*3*	*6*
Soybeans	*44*	*13*	*133*	*140*	*101*
Misc Farm Product	*0*	*0*	*0*	*18*	*28*
Nonmetallic Minerals	**4,113**	**3,946**	**3,826**	**4,019**	**3,679**
Sand/Gravel	*4,072*	*3,901*	*3,807*	*4,004*	*3,668*
Misc Nonmetallic	*41*	*45*	*19*	*14*	*11*
Food and Kindred	7	0	0	0	0
Pulp and Paper	0	0	0	0	0
Chemicals	**64**	**72**	**140**	**125**	**126**
Fertilizer	*64*	*72*	*140*	*125*	*126*
Other Chemicals	*0*	*0*	*0*	*0*	*0*
Petroleum (including Coke)	44	13	68	73	104
Stone/Clay/Glass	85	83	98	98	257
Primary Metals	0	6	3	12	14
Waterway Materials	305	232	290	216	110
Other (Misc Mineral Products)	0	0	0	84	
Total Commercial	4,671	4,402	4,656	4,957	4,534
Total Long-Haul Commercial	293	269	269	736	757

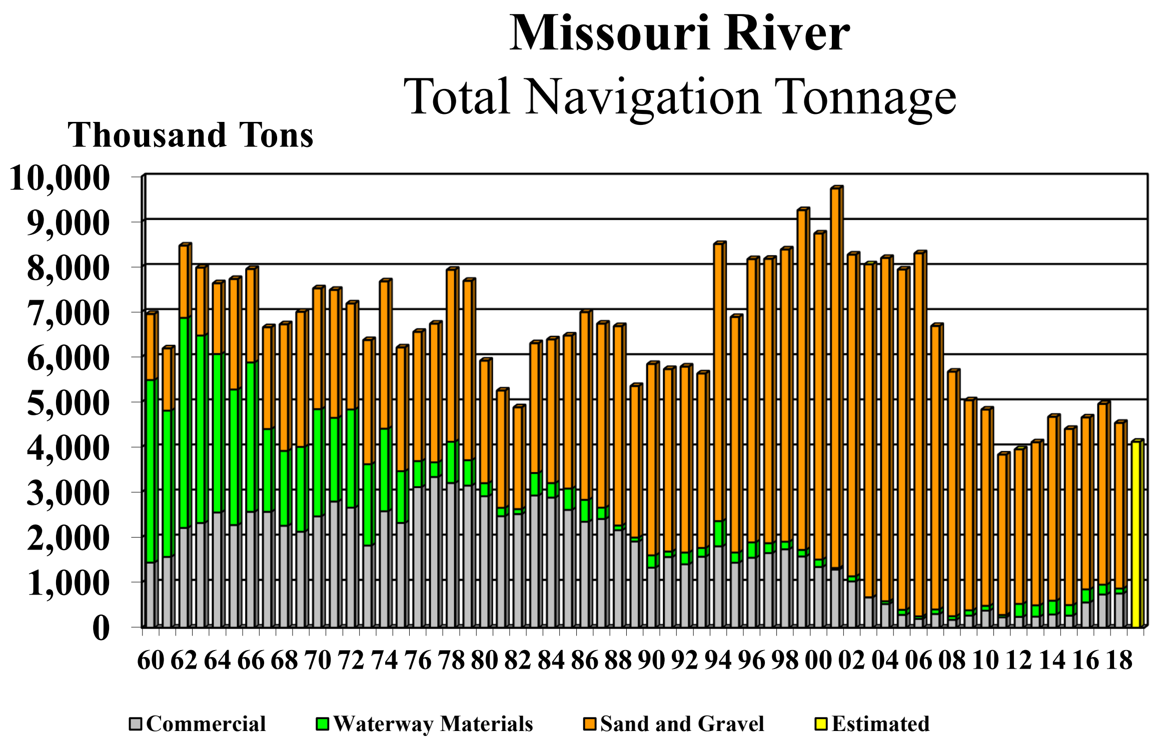


Figure 30A. Missouri River total navigation tonnage from 1960 to 2019 (estimated).

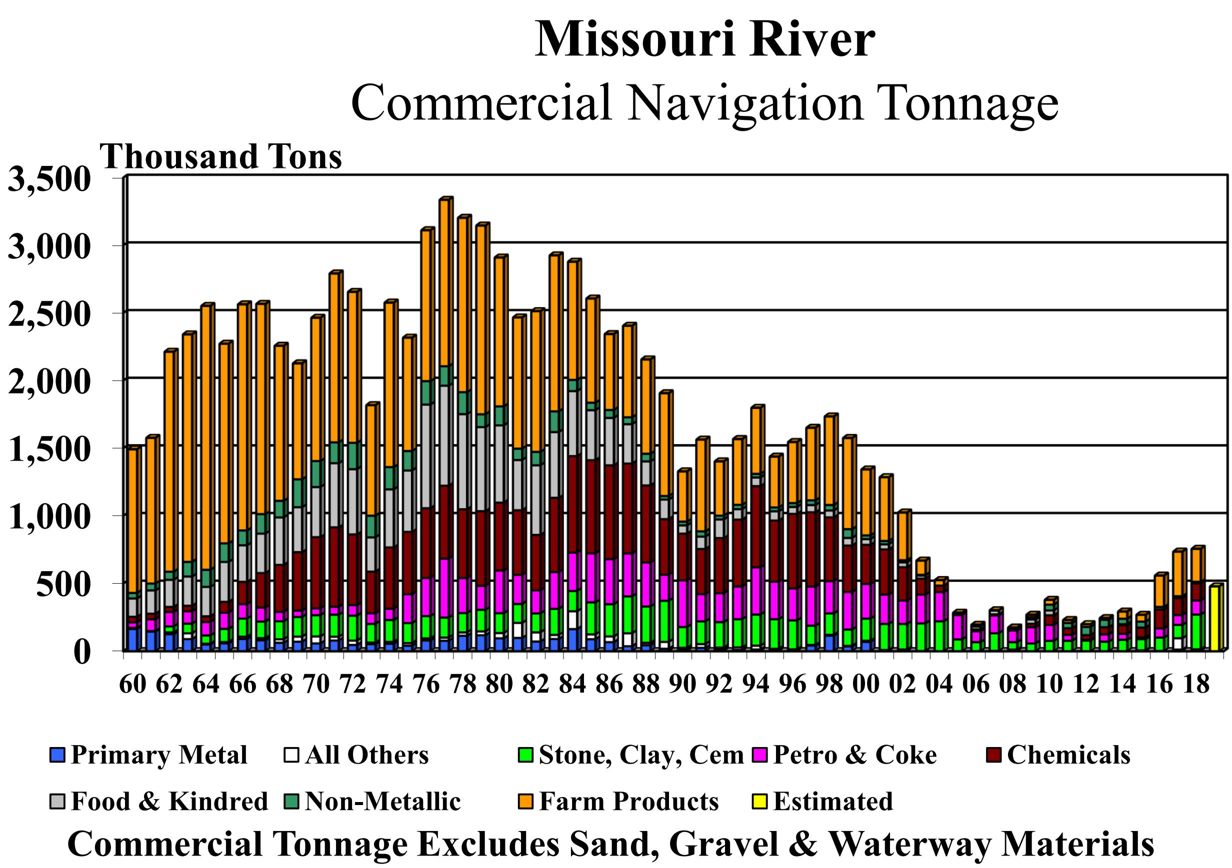


Figure 30B. Missouri River commercial navigation tonnage from 1960 to 2019 (estimated).

Missouri River

Total Navigation Tonnage Value - 2019 Present Worth

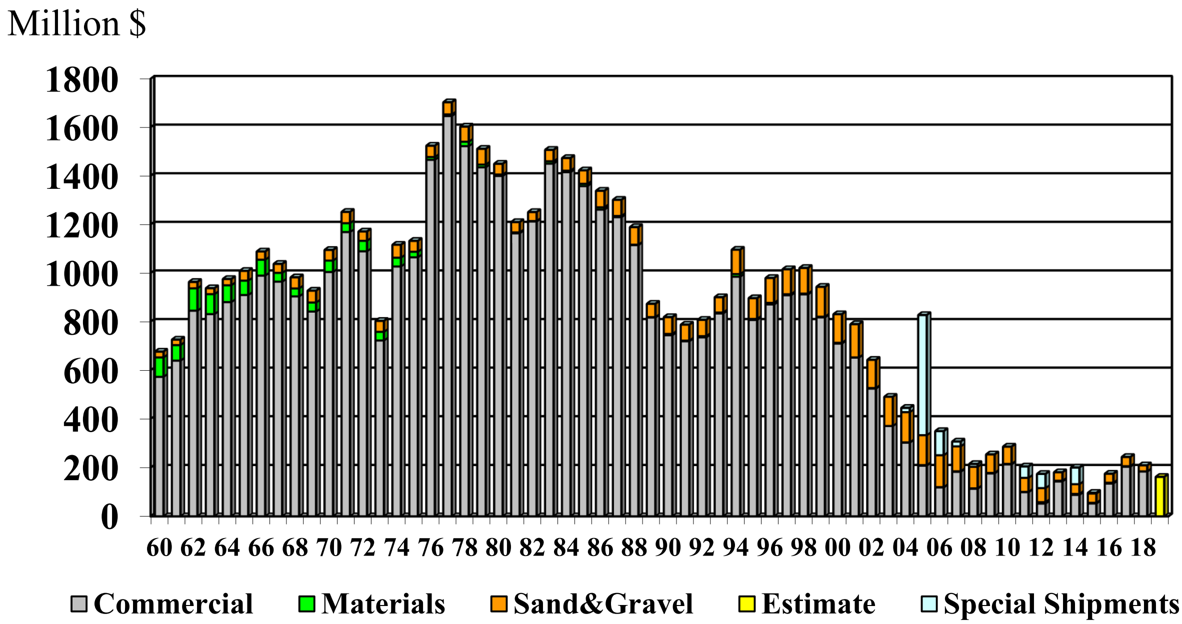


Figure 31A. Total navigation tonnage value using 2019 present worth computations.

Missouri River

Commercial Navigation Tonnage Value – 2019 Present Worth

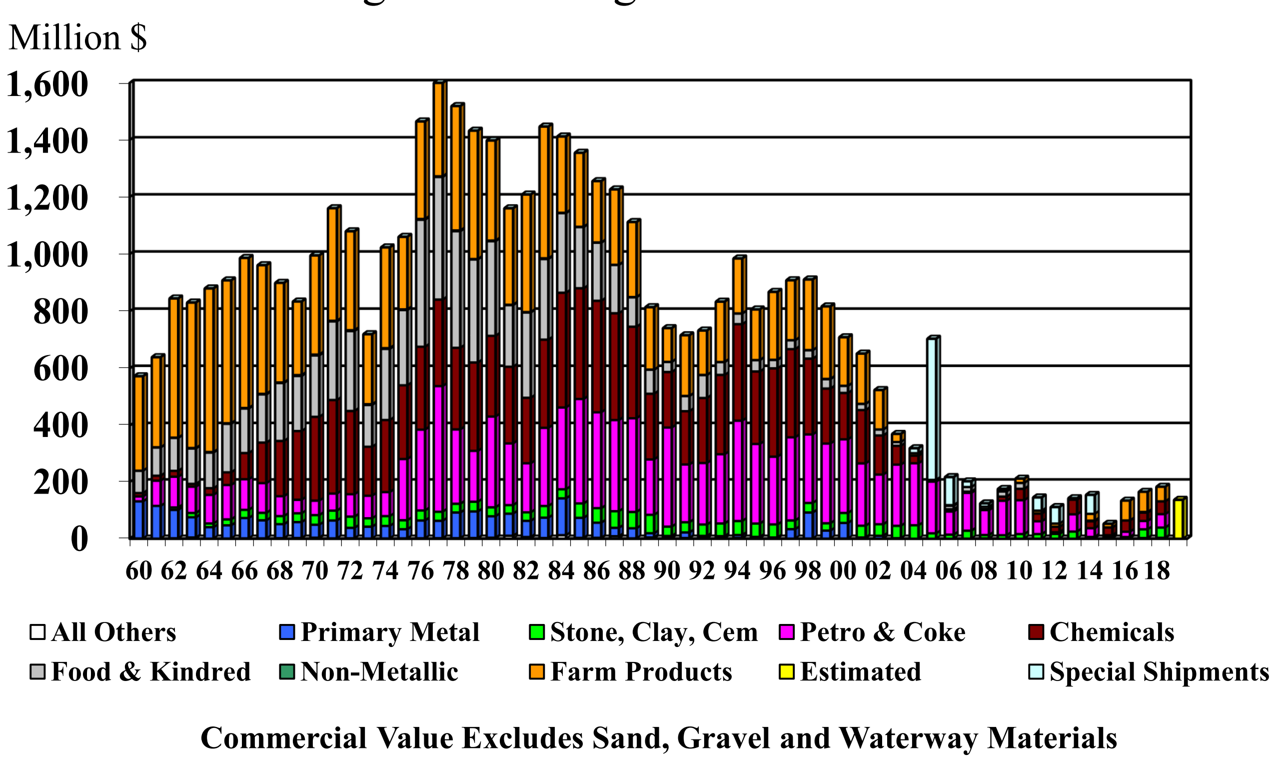


Figure 31B. Commercial navigation tonnage value using 2019 present worth computations.

Table 17
Navigation Season Target Flows
(1,000 cfs)

Year	Months	Sioux City	Omaha	Nebraska City	Kansas City
1967	Apr-Jun	28	28	34	38
	Jul-Nov	31	31	37	41
1968	Apr-Nov	31	31	37	41
1969	Apr-Jun(1)	35-40	35-40	41-46	45-50
	Jul(1)	36	36	42	46
	Aug-Sep(1)	50-55	50-55	55-60	55-60
	Oct-Nov(1)	40-45	40-45	45-50	50-55
1970	Apr-May	31	31	37	41
	May-Sep(1)	36	36	42	46
	Oct-Nov(1)	40	40	46	50
1971	Apr-May(1)	36	36	42	46
	May-Nov(1)	45-50	45-50	50-55	55-60
1972	Apr-Nov(1)	40-50	40-50	45-55	50-60
1973-74	Apr-Nov	31	31	37	41
1975	Apr	31	31	37	41
	May-Nov(1)	35-60	35-60	41-66	45-70
1976	Apr-Jul(1)	34-38	34-38	40-44	44-48
	Aug-Dec(1)	31-34	31-34	37-40	41-44
1977	Apr-Nov	31	31	37	41
1978	Apr	31	31	37	41
	May-Jul(1)	35-46	35-46	41-52	45-56
	Aug-Nov(1)	46-51	46-51	52-57	56-61
1979	Apr-Jul(1)	36-42	36-42	42-48	46-52
	Aug-Nov(1)	31-36	31-36	37-42	41-46
1980	Apr-Nov	31	31	37	41
1981	Apr-Nov(2)	31	31	37	41
1982	Apr-Sep	31	31	37	41
	Oct	31-36	31-36	37-42	41-46
	Nov-Dec(1)	36-46	36-46	42-52	46-56
1983	Apr-Jun	31	31	37	41
	Jul	31-36	31-36	37-42	41-46
	Aug-Nov(1)	36	36	42	46
1984	Apr-Jun	31	31	37	41
	Jul-Dec(1)	31-44	31-44	37-50	41-54
1985	Apr-Dec	31	31	37	41
1986	Apr(1)	36-41	36-41	42-47	46-51
	May-Dec(1)	41-46	41-46	47-52	51-56
1987	Apr-Nov	31	31	37	41
1988	Apr-Nov(2)	31	31	37	41
1989	Apr-Aug(3)	28	28	34	38
	Sep-Oct(3)	28	28	34	35

Year	Months	Sioux City	Omaha	Nebraska City	Kansas City
1990-93	Apr-Oct(4)	25	25	31	35
1994	Apr-Dec	31	31	37	41
1995	Apr-May	31	31	37	41
	Jun-Dec(1)	46-56	46-56	52-62	56-66
1996	Apr(1)	41	41	47	51
	May(1)	41-51	41-51	47-57	51-61
	Jun-Dec(1)	56	56	62	66
1997	Apr-Dec(5)	*	*	*	*
1998	Apr-Dec(5)	31	31	37	41
1999	Apr-Dec(1)	31-43	31-43	37-49	41-53
2000	Apr-Jun	31	31	37	41
	Jul-Dec(3)	29.5	29.5	35.5	39.5
2001	Apr-Dec(3)	28	28	34	38
2002	Apr-Jun(3)	27	27	33	37
	Jul-Dec(3)	25	25	31	35
2003	Apr-Nov(4)	25	25	31	35
2004-08	Apr-Oct(6)	25	25	31	35
2009	Apr-Nov(7)	25/31	25/31	31/37	35/41
2010	Apr-Dec(1)	31-43	31-43	37-49	41-53
2011	Apr(1)	31-41	31-41	37-47	41-51
	mid-Apr(1)	41-46	41-46	47-52	51-56
	May(1)	46-56	46-56	52-62	56-66
	mid-May(5)	*	*	*	*
2012	Apr-Dec	31	31	37	41
2013	Apr-Jun(6)	25	25	31	35
	Jul-Dec(3)	28	28	34	38
2014	Apr-Jun(3)	28	28	34	38
	Jul-Dec(1)	31-46	31-46	37-52	41-56
2015	Apr-Dec	31	31	37	41
2016	Apr-Dec	31	31	37	41
2017	Apr-Jun(1)	36	36	42	46
	Jul-Dec	31	31	37	41
2018	Apr-Jun(1)	35-56	36-56	42-62	46-66
	Jul-Dec(5)	*	*	*	*
2019	Apr-Dec(5)	*	*	*	*

(1) Downstream flow targets above full-service navigation level as a flood control storage evacuation measure.
(2) Full service flows provided for shortened season.
(3) Navigation targets below full service as a water conservation measure.
(4) Navigation targets at minimum service as a water conservation measure.
(5) Releases determined by flood control storage evacuation criteria and not adjusted to meet specific navigation targets.
(6) Minimum service targets at Sioux City and Omaha not met during periods when there was no navigation in those reaches.
(7) Minimum service targets at Sioux City were not met during periods when there was no navigation in those reaches.

Table 18
Missouri River Navigation
Tonnage and Season Length

Year	Reservoir System Supported Length of Season (Months)	Commercial (Tons) (1)	Total Traffic (Tons) (2)	Total Traffic (1,000 Ton-Miles) (2)
1967 (3)	8	2,562,657	6,659,219	1,179,235
1968	8 (4)	2,254,489	6,724,562	1,047,935
1969	8 (4)	2,123,152	7,001,107	1,053,856
1970	8 (5)	2,462,935	7,519,251	1,190,232
1971	8 (4)	2,791,929	7,483,708	1,329,899
1972	8 (4)	2,665,579	7,182,841	1,280,385
1973	8	1,817,471	6,370,838	844,406
1974	8	2,576,018	7,673,084	1,227,525
1975	8 (4)	2,317,321	6,208,426	1,105,811
1976	8 (4)	3,111,376	6,552,949	1,535,912
1977	8	3,335,780	6,734,850	1,596,284
1978	8 (4)	3,202,822	7,929,184	1,528,614
1979	8 (4)	3,145,902	7,684,738	1,518,549
1980	8	2,909,279	5,914,775	1,335,309
1981	7 1/4 (6)	2,466,619	5,251,952	1,130,787
1982	8 (4)	2,513,166	4,880,527	1,131,249
1983	8 (4)	2,925,384	6,301,465	1,300,000
1984	8 (4)	2,878,720	6,386,205	1,338,939
1985	8 (4) (7)	2,606,461	6,471,418	1,201,854
1986	8 (4) (7)	2,343,899	6,990,778	1,044,299
1987	8	2,405,212	6,735,968	1,057,526
1988	7 1/2	2,156,387	6,680,878	949,356
1989	6 3/4	1,906,508	5,352,282	796,799
1990	6 3/4	1,329,000	5,841,000	552,509
1991	6 3/4	1,563,000	5,729,000	537,498
1992	6 3/4	1,403,000	5,783,000	593,790
1993	8 (8)	1,570,000	5,631,000	615,541
1994	8	1,800,000	8,501,000	774,491
1995	8 (4)	1,439,000	6,884,000	604,171
1996	8 (4)	1,547,000	8,165,000	680,872
1997	8 (4)	1,651,000	8,172,000	725,268
1998	8 (4)	1,735,000	8,379,000	777,727
1999	8 (4)	1,576,000	9,252,000	699,744

Year	Reservoir System Supported Length of Season (Months)	Commercial (Tons) (1)	Total Traffic (Tons) (2)	Total Traffic (1,000 Ton-Miles) (2)
2000	8	1,344,000	8,733,000	628,575
2001	8	1,288,000	9,732,000	566,150
2002	8 (9)	1,009,000	8,266,000	409,980
2003	8 (10)	667,000	8,050,000	256,788
2004	6 1/2 (11)	525,498	8,192,219	181,995
2005	6 1/2 (11)	284,641	7,935,747	129,882
2006	6 1/2 (11)	195,290	8,295,226	84,483
2007	6 3/4 (11)	302,769	6,684,625	119,177
2008	7 (11)	174,800	5,670,968	86,203
2009	8	269,563	5,035,744	114,865
2010	8(4)	379,492	4,829,714	132,747
2011	8(4)	230,439	3,831,925	62,253
2012	8	197,000	3,906,000	56,631
2013	8	244,576	4,104,505	110,280
2014	8(4)	293,125	4,670,661	89,932
2015	8	269,200	4,402,000	78,300
2016	8	559,020	4,655,884	201,943
2017	8	736,187	4,956,563	221,936
2018	8(4)	756,530	4,534,119	223,268
2019	8(4)(13)(14)	478,700	4,115,829 (13)	171,661 (13)

(1) Includes commercial tonnage except for sand and gravel or waterway materials. Tonnage compiled by Waterborne Commerce Statistics Center (WCSC).
(2) Includes commodities; sand, gravel, and crushed rock; and waterway improvement materials. Tonnage by WCSC.
(3) Mainstem Reservoir System first reached normal operating storage level in 1967.
(4) 10-day extension of season provided.
(5) 10-day extension and 10-day early opening provided.
(6) Full service flows for shortened season in preference to reduced service.
(7) 10-day extension provided for 1985 season in trade for 10-day delayed support of 1986 season.
(8) Lower Missouri River closed: 57 days in 1993, 20 days in 1995, and 18 days in 1999.
(9) To protect endangered shore birds below Gavins Point Dam, the Corps did not support navigation from July 3 to August 14, 2002. Average days towing industry off the river was 23 days.
(10) 6-day shortening of season to follow CWCP. From Aug 11 to Sep 1 Corps did not support navigation flows to comply with lawsuit to follow 2000 Biological Opinion. Navigation industry left the river during this period.
(11) Season shortening; 47 days, 2004; 48 days, 2005; 44 days, 2006; 35 days, 2007; 30 days, 2008
(12) Estimated using boat report barge counts.
(13) Estimated using WCSC preliminary projections.
(14) Portions of the Lower Missouri River closed: 45 days in 2019.

Table 19
2019 Missouri River Closure and Re-Opening Events*

	Missouri River River Mile and River Reach		
Date	**Closed**	**Re-Opened**	**Open**
March 15	625 – 226		811- 625, 226 - mouth
April 6		625 – 226	811 - mouth
April 14	218 – 216		811 - 218, 216 - mouth
April 26		218 – 216	811 – mouth
June 2	625 – 226		811 - 750
June 13		750 - mouth	811- mouth

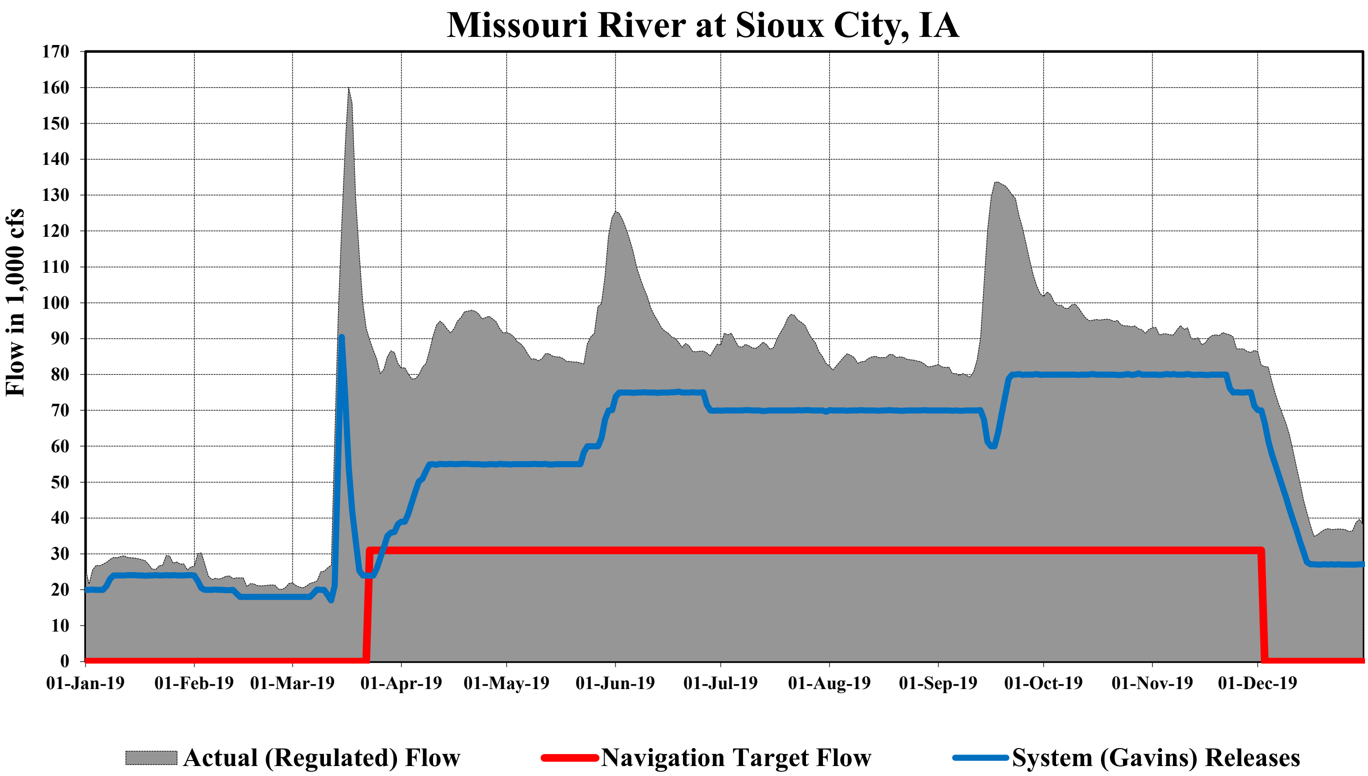
** A portion of the lower Missouri River was closed to navigation in 2019 and the sum of those closure periods was 45 days. Source: USCG Spring 2019 High Water Summary.*

6. Power – Eastern Division, Pick-Sloan Missouri Basin Program (P-S MBP)

The hydropower energy generated by the System is transmitted over a federal transmission system that traverses 7,923 circuit miles. On October 1, 2015 Western's transmission system became integrated with the Southwest Power Pool (SPP) regional transmission organization. During 2019, service was provided to approximately 340 wholesale customers. Customers receiving service include 199 municipalities, 2 federal agencies, 30 state agencies, 28 USBR projects, 5 irrigation districts, 33 rural electric cooperatives, 6 public utility districts, 5 private utilities, 26 Native American services and 6 power marketers. Additional marketing benefits have been realized with Western becoming an asset-owning market participant within the SPP integrated market place in 2017.

Per the Omaha Public Power District (OPPD) statistics, the average OPPD customer uses approximately 11,515 kilowatt hours (kWh) of energy annually. Based on the total System generation of 13.0 billion kWh, the energy generated in 2019 by this portion of the federal power system could have supplied all of the yearly needs of about 1,130,000 residential OPPD customers. In addition to the clean, renewable energy supplied to our customers, System hydropower provides an added measure of stability to the SPP regional power system. Large coal-fired and nuclear units are backed up by other SPP member resources and the federal hydropower generation. Members of the SPP market benefit by being able to call for reserves during emergency events. In addition, hydropower and other SPP generation are integrated with wind generation to provide balance to the SPP system.

The reliability of System hydropower helps to maintain adequate reserves in both the Northwest Power Pool in Western Area Power Administration, Upper Great Plains West (WAUW) and the SPP.



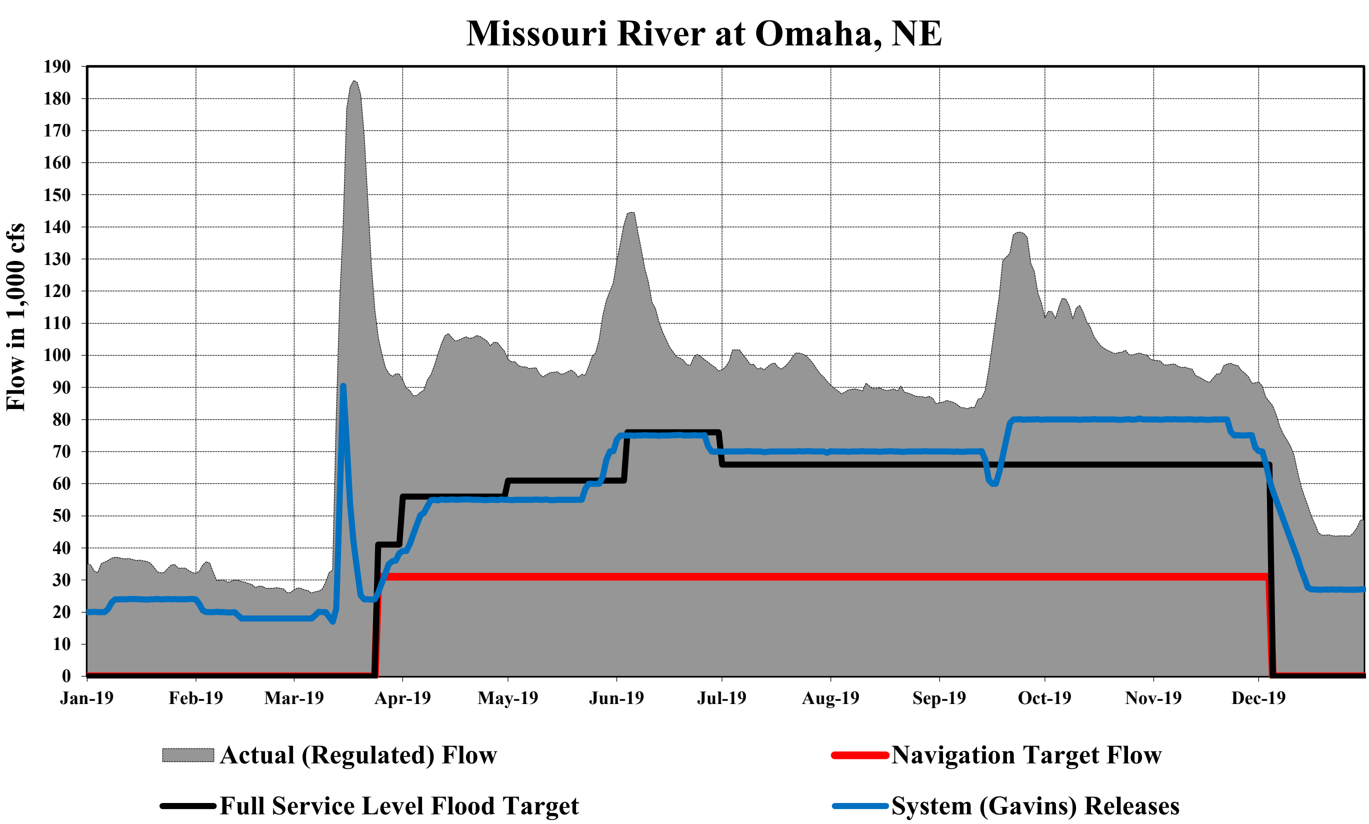
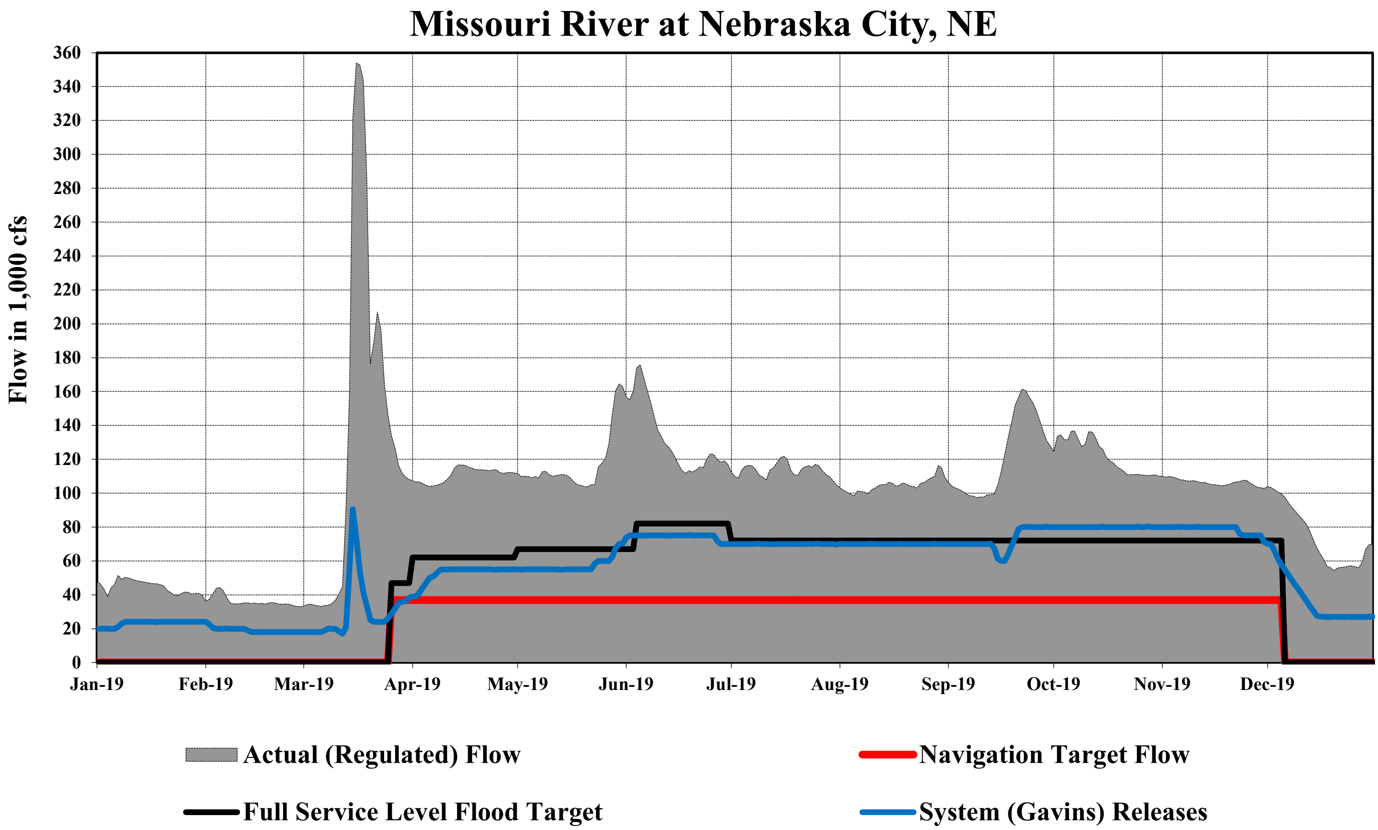


Figure 32A. Actual flow, System releases, navigation target flows, and service level flood target flows –Sioux City, IA and Omaha, NE (calendar year).



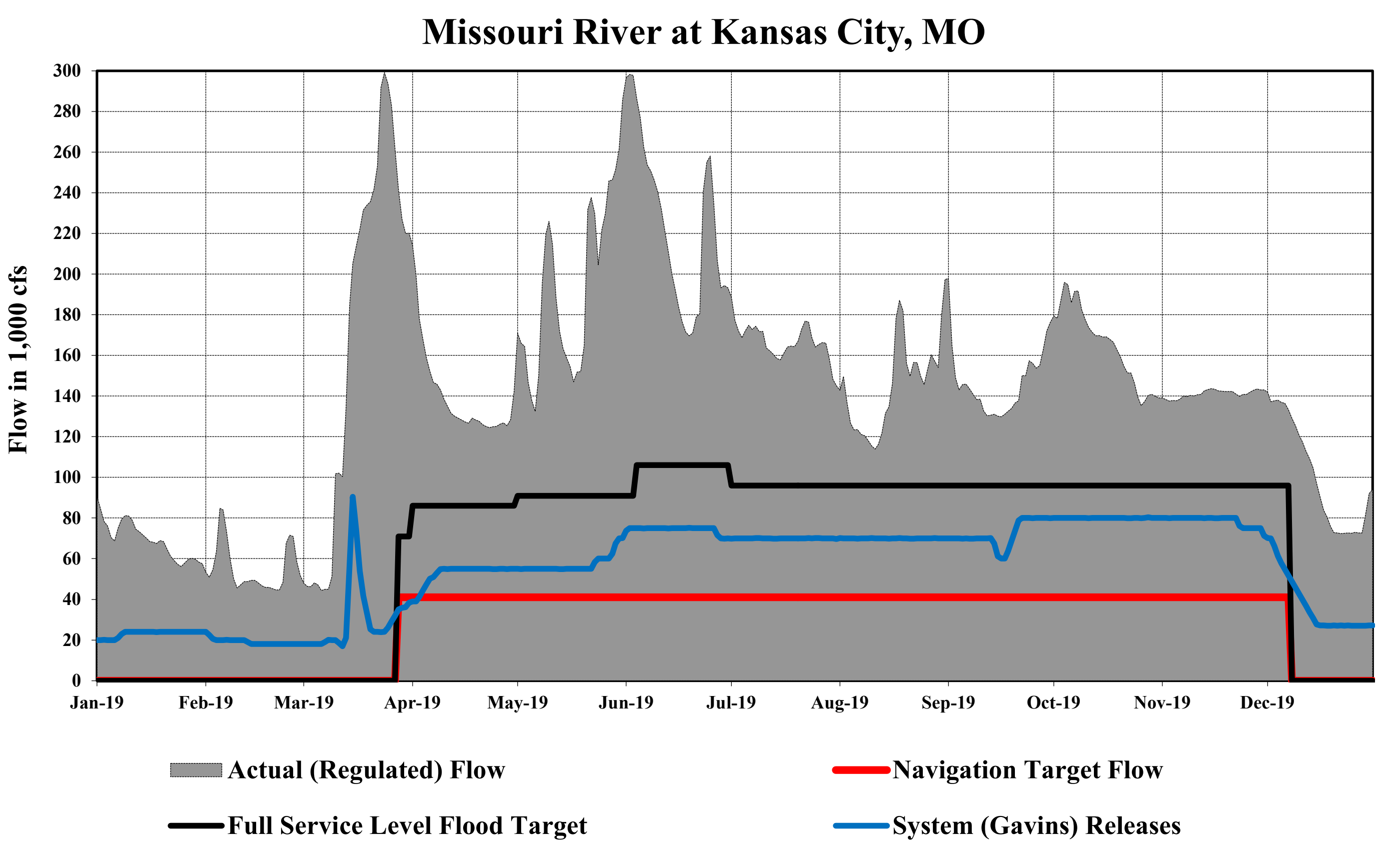


Figure 32B. Actual flow, System releases, navigation target flows, and service level flood target flows –Nebraska City, NE and Kansas City, MO (calendar year).

Hydropower generation in 2019 was 13.0 billion kWh, which was 138 percent of average since the System first filled in 1967 and the highest since 1997 when 14.6 billion kWh were generated. The 2019 generation was 0.7 billion kWh more than the 2018 generation of 12.3 billion kWh and 8.1 billion kWh more than the record low of 4.9 billion kWh, generated in 2008. Total generation was above average in 2019 due to the above-average releases being made during the above-average upper Basin runoff. Western purchased about 639 million kWh between January 1 and December 31, at a cost of $18.4 million, to supplement System hydropower production.

System generation with individual project distribution for each calendar year in million megawatt hours (MWh) since 1954 is shown on ***Figure 33***. The total generation from the federal system (peak capacity and energy sales) for 2019 is shown in ***Table 20***. The tabulations in ***Table 21*** and ***Table 22*** summarize the peak and total gross generation for the Eastern Division, P-S MBP marketing area system for the past operating year. Actual settlement figures at the end of the billing periods differ somewhat from the calendar month figures shown.

Table 20
Gross Federal Power System Generation – January 2019 through December 2019

	Energy Generation 1000 kWh	**Peak Hour kW**	**Generation Date**
Corps Powerplants – Mainstem			
Fort Peck	1,242,109	193,000	September 27
Garrison	3,194,637	554,000	June 23
Oahe	4,191,230	736,000	July 25
Big Bend	1,529,713	426,000	November 25
Fort Randall	2,205,114	362,000	September 11
Gavins Point	655,411	107,000	September 16
Corps Subtotal	**13,018,214**	2,227,000	August 17
USBR Powerplants			
Canyon Ferry	369,426	56,000	November
Yellowtail*	458,891	95,500	March
USBR Subtotal	828,317		
Federal System Total	**13,846,531**		

* Includes only half of total Yellowtail generation, which is marketed by the Eastern Division, P-S MBP.

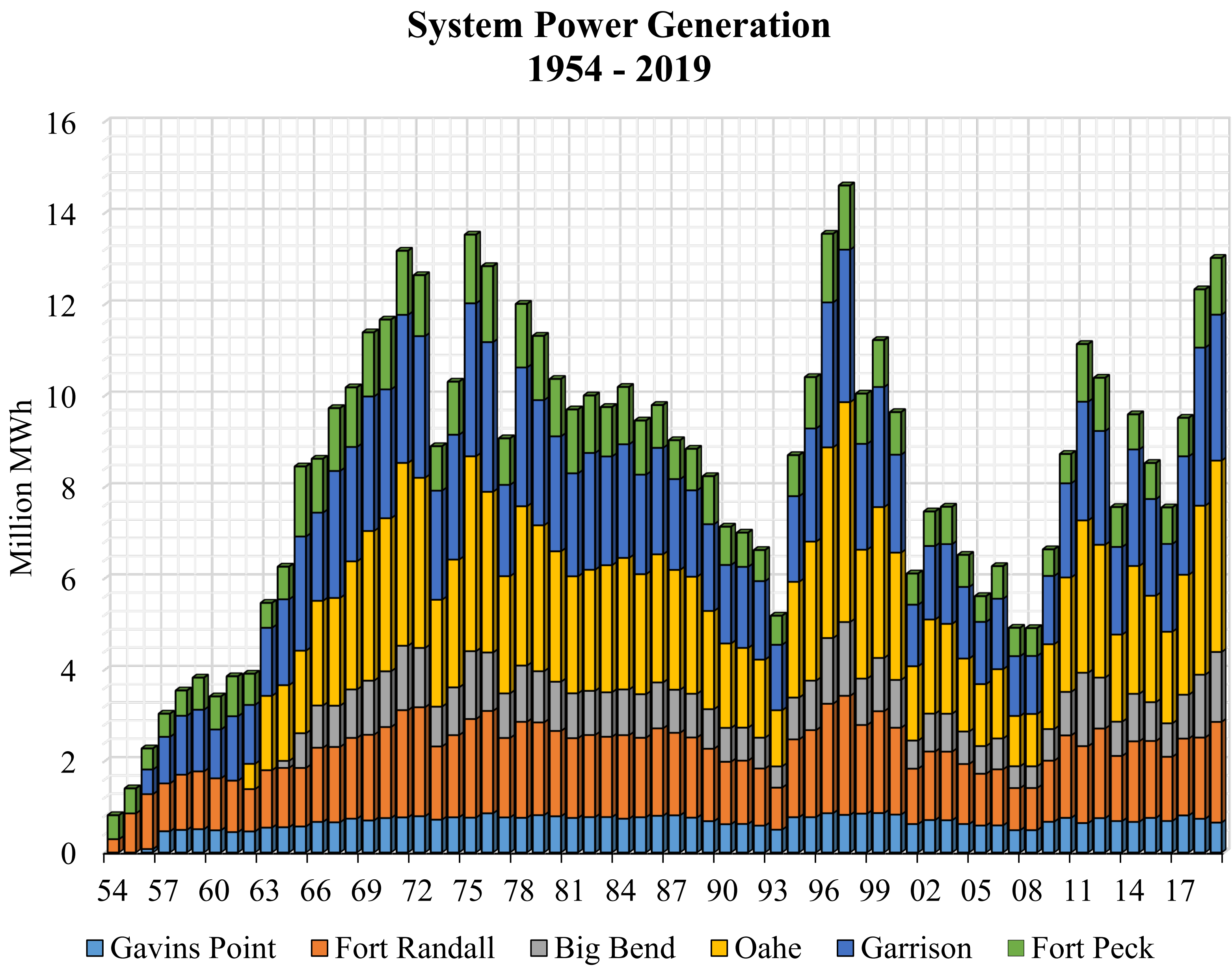


Figure 33. System power generation by project from 1954 to 2019.

Table 21
Historical Generation and Load Data – Peaks
Eastern Division, Pick-Sloan Missouri Basin Program*
Data at Plant (1000 kW)
January 1, 2019 through December 31, 2019

Period	Corps of Engineers Hourly Generation (Gross)**	(plus)	USBR Hourly Generation (Gross)**	(equals)	Federal Hour Generation (Gross)**	(plus)	Interchange and Purchases Received**	(equals)	Peak Total System Load	Peak Date	Peak Hour
January	1,568		95		1,663		138		1,801	Jan 30	900
February	1,433		96		1,529		372		1,901	Feb 08	900
March	1,268		79		1,347		497		1,844	Mar 04	800
April	1,199		84		1,283		330		1,613	Apr 01	1000
May	1,406		113		1,519		0		1,519	May 14	1900
June	1,954		109		2,063		0		2,063	Jun 28	1700
July	2,111		123		2,234		0		2,234	Jul 15	1800
August	2,092		111		2,203		0		2,203	Aug 05	1700
September	2,074		99		2,173		0		2,173	Sep 03	1700
October	1,903		96		1,999		0		1,999	Oct 28	1000
November	1,847		95		1,942		0		1,942	Nov 11	1900
December	1,537		112		1,649		179		1,828	Dec 09	1900

* This tabulation summarizes the total gross generation and power operations for the Eastern Division marketing area system shown on Table 20.
** During hour of peak total system load.

Table 22
Historical Generation and Load Data – Total
Eastern Division, Pick-Sloan Missouri Basin Program*
Data at Plant (1000 kWh)
January 1, 2019 through December 31, 2019

Period	Corps of Engineers Generation (Gross)	(plus)	USBR Generation (Gross)	(equals)	Federal Generation (Gross)	(plus)	Scheduled Interchange and Purchases Received	(equals)	Total System Load
January	803,711		51,228		854,939		109,232		964,171
February	715,685		41,129		756,814		148,198		905,012
March	473,221		37,494		510,715		272,143		782,858
April	793,066		59,866		852,932		38,770		891,702
May	1,022,341		76,991		1,099,332		473		1,099,805
June	1,223,389		75,124		1,298,513		1,629		1,300,142
July	1,490,277		88,170		1,578,447		2,605		1,581,052
August	1,540,581		75,157		1,615,738		2,074		1,617,812
September	1,394,191		67,780		1,461,971		825		1,462,796
October	1,365,871		68,396		1,434,267		380		1,434,647
November	1,276,870		69,296		1,346,166		548		1,346,714
December	919,011		60,785		979,796		61,694		1,041,490

*Powerplants from Table 20.

7. Recreation

The System reservoirs provide outstanding opportunities for boating, fishing, swimming, camping and other outdoor recreation pursuits. Tourism related to the reservoirs is a major economic factor in all of the states adjoining the System. However, when the reservoirs are drawn down due to extended drought periods, recreation may be adversely affected primarily due to access issues. Most of the recreational impacts of a drought are experienced at the upper three large reservoirs – Fort Peck, Garrison and Oahe. Due to the manner in which they are regulated, the lower three reservoirs are not significantly impacted by drought. Reservoir levels at the upper large reservoirs were higher than average during the 2019 recreation season due to high runoff in the upper Basin. No accessibility problems were reported at System projects' boat ramps.

Access areas at the upper three reservoirs include Corps-owned, as well as Tribal, state and privately-owned, facilities. In 2002, many of the federal recreation areas and boat ramps in South Dakota were turned over in fee title to the State of South Dakota and the Bureau of Indian Affairs through the Title VI process. Since the land transfer, both the Federal Treasury and the Corps have provided money to the South Dakota Game Fish and Parks, Cheyenne River Sioux Tribe and Lower Brule Sioux Tribe for operations and stewardship of the Title VI lands they received. Congress is also capitalizing a trust fund to cover these costs in the future.

The methodology used for the Corps to determine visitation hours was revised during 2013. No visitation data is available for 2013. Visitation data for fiscal years 2014-19 is presented in ***Table 23***. The new methodology represents the number of unique individual visits for a specific activity or purpose that people used the reservoir and surrounding lands in any capacity. For example, a group of four people camping for the weekend counts as four visits. Four people pheasant hunting together counts as four visits per day. There are different weights and load factors assigned to different site types. The methodology also adds in a certain ratio of dispersed use for areas that the Corps has no feasible way to monitor or meter.

Table 23
Visitation at System Reservoirs (Visits)

Project	2014	2015	2016	2017	2018	2019
Fort Peck	548,073	407,783	544,689	543,767	610,148	653,190
Garrison	1,351,900	1,488,471	1,590,185	2,172,356	2,674,812	2,492,706
Oahe	1,934,347	2,361,246	2,411,398	1,988,843	1,791,821	3,147,201
Big Bend	931,574	1,268,595	1,062,289	977,342	1,049,286	980,489
Fort Randall	896,671	896,847	836,647	898,915	853,683	772,438
Gavins Point	2,175,314	2,369,151	1,955,423	1,991,084	1,787,941	1,920,086
System Total	**7,837,879**	**8,792,093**	**8,400,631**	**8,572,307**	**8,767,691**	**9,966,110**

8. Fish and Wildlife

a. Fish Management

Rainbow smelt are the primary forage species in both Garrison and Oahe reservoirs. Successful rainbow smelt reproduction is dependent on many factors including stable reservoir levels during the smelt spawning period, generally in April and early May. Most eggs are laid in water less than a foot deep and are subject to desiccation through wave action and slight drops in water level.

The above-average upper Basin runoff in 2019 resulted in generally steady-to-rising pools in the Fort Peck, Garrison and Oahe reservoirs throughout the spring and early summer. Oahe did decline slightly in late April and early May, but began rising again in mid-May. Evacuation of stored flood waters in 2019 may have displaced rainbow smelt and other game species to downstream locations.

b. Threatened and Endangered Species (T&E)

(1) Pallid Sturgeon

For detailed discussion on Missouri River activities for the pallid sturgeon, see the Missouri River Recovery Program 2019 Adaptive Management ESA Compliance Report: (https://www.nwo.usace.army.mil/mrrp).

(2) Piping Plovers and Least Terns

Since 1986, System regulation has considered impacts of operations to the piping plover (plover, threatened) and least tern (tern, endangered), when they were federally listed as T&E species. The terns and plovers nest on sparsely vegetated sandbars, islands and shoreline of the Missouri River and the reservoirs. Real-time telemetered streamgaging stations have been installed along the Missouri River to monitor river stages and flows during the nesting season. These gages provide a check, as well as a stage history, throughout the season to help relate the effects of regulation and natural events at intervals along the river. The gage data must be supplemented with observations of nesting activities and conditions to provide the information that is needed for regulation of the reservoirs. A dynamic flow routing model has been developed to predict river stages along the river reaches downstream from Fort Peck, Garrison, Fort Randall and Gavins Point for different combinations of daily and hourly power peaking. However, only the reach downstream of Garrison has been updated with post-2011 flood cross section data.

Beginning in 1999, Omaha District created a computerized T&E species Data Management System (DMS). Report data, which is updated daily, includes nest records, census and productivity data, site descriptions, field journals and field observations. This database is a valuable tool in aiding regulation decisions benefiting the terns and plovers in years when the reservoirs are regulated to protect nesting terns and plovers.

Although the Corps prevented inundation of nests where possible and created habitat following the listing, fledging ratios continued to be lower than predicted by the USFWS 1990 Biological Opinion until 1998, when fledge ratios exceeded the goal for both species. Predation, habitat degradation, severe weather, nest inundation, record runoff and other factors contributed to the low fledging rates. The record fledging that occurred for both species between 1998 and 2005 is primarily attributed to the large amount of habitat created by the high runoff years of 1995, 1996 and 1997 and the declining reservoir levels during the 2000-07 drought. The creation of additional habitat has also allowed greater flexibility in the release levels at Fort Randall and Gavins Point, the lower two System projects.

The above-average 2019 runoff resulted in high or rising reservoirs and above average releases during the nesting season. High releases, particularly from Fort Randall and Gavins Point, and high reservoir levels both limited habitat and affected nest success. Known and presumed predation throughout the system along with nest inundation was the most common cause of nest failure in 2019. A detailed description of the factors affecting tern and plover nesting, fledge ratios and habitat conditions and creation activities by reservoir and river reach can be found in the Missouri River Recovery Program 2019 Adaptive Management ESA Compliance Report: (https://www.nwo.usace.army.mil/mrrp/).

9. Cultural Resources

As acknowledged in the 2004 Programmatic Agreement (PA) for the Operation and Management of the Missouri River Main Stem System, wave action and the fluctuation of reservoirs levels results in erosion along the banks of the reservoirs. Shoreline erosion can have severe effects on cultural resources. During drought conditions, cultural resource sites are exposed as the pool levels decline.

The PA established a shared stewardship philosophy of protection of historic properties. The objective of a PA is to address "…potential adverse effects of complex projects or multiple undertakings…" and to collaboratively develop a preservation program that would avoid, minimize and mitigate the effects of the System regulation. All Tribes, whether signatory to the PA or not, may request government-to-government consultation on System regulation and the resulting effect on historic and cultural properties and other resources.

A Cultural Resource Program Five Year Plan was developed in consultation with Tribes, States, Agencies and interested parties. This plan outlines how the Corps will accomplish its responsibilities under the National Historic Preservation Act and the PA. The plan includes inventory, testing and evaluation, mitigation and other specific activities that will allow the Corps to avoid, minimize and mitigate the adverse effects to cultural sites on the Corps' lands within the System. The "Final Five Year Plan", dated February 2012 (see website http://www.nwo.usace.army.mil/Missions/CivilWorks/CulturalResources.aspx) is currently being implemented.

One consultation meeting on the PA was held during the 2019 reporting period. The purpose of consultation meetings is to engage in communications and discuss whether operational changes are likely to affect historic and cultural properties, identify those properties and discuss how to address those affects.

A MRBWM letter, dated September 18, 2019, was sent to the Missouri River Basin Tribes offering consultation on the 2019-2020 AOP. To date, no Tribes have requested consultation nor provided verbal or written comments on the AOP. The MRBWM office hosts semi-annual public meetings in locations throughout the Missouri River Basin. At these meetings, stakeholders have the opportunity to provide input on the upcoming year's reservoir operations. One tribe was recorded participating in the fall AOP public meetings, which were held in October 2019 in seven locations throughout the Missouri River Basin.

The Corps actively addresses shoreline erosion which can damage or significantly alter cultural resource sites. During 2020, three Omaha District cultural resource protection projects are underway or planned. One of those is a Garrison stabilization project that is in the second phase of construction. The project was not completed in recent years due to high water and is now planned for completion in 2020, reservoir conditions permitting. Two stabilization projects are planned for completion on Fort Randall in 2020.

U.S. ARMY CORPS OF ENGINEERS
NORTHWESTERN DIVISION
MISSOURI RIVER BASIN WATER MANAGEMENT DIVISION

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)	1,031	2,279	2,632
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 32,000 cfs - 128,000 cfs			43
1351-1355(10) 25,000-100,000 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
982	1,720	726	9,369 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 2019

2019 USGS Peak Stages and Flows Compared to Historic Peak Stages and Flows in the Missouri River Basin.

River Location	Peak Flows					Peak Stages				
	2019		Historic		Difference	2019		Historic		Difference
	Date	cfs	Date	cfs	cfs	Date	ft	Date	ft	ft
Moreau River at Whitehorse, SD	3/25/2019	18,500[p]	3/20/2011	34,200	-15,700	3/25/2019	27.8	3/21/1997	27.7	0.1
Platte Creek near Platte, SD	9/12/2019	12,200[p]	6/22/2011	3,570	8,630	9/12/2019	21.2	7/6/2011	14.7	6.5
Niobrara River at Verdel, NE	3/14/2019	123,000[p]	3/27/1960	39,000	84,000	3/14/2019	19.4	3/12/1966	10.6	8.8
Niobrara River at Niobrara, NE	3/14/2019	n/a	n/a	n/a	n/a	3/14/2019	41.6	7/22/2010	34.9	6.7
James River at Scotland, SD	9/14/2019	59,000	6/23/1984	29,400	29,600	9/14/2019	22.2	6/23/1984	20.5	1.7
James River at Yankton, SD	9/14/2019	47,200	3/28/2011	29,200	18,000	9/14/2019	27.8	6/23/1984	24.3	3.5
EF Vermillion River at Parker, SD	9/13/2019	6,000	7/31/2010	4,760	1,240	9/13/2019	17.6	3/13/2010	14.9	2.7
Big Sioux River at Dell Rapids, SD	9/13/2019	22,500	4/9/1969	41,300	-18,800	9/13/2019	16.7	4/9/1969	16.5	0.2
Split Rock Creek at Corson, SD	9/12/2019	20,100	5/8/1993	18,900	1,200	9/12/2019	19.0	5/8/1993	17.6	1.4
Floyd River at James, IA	3/15/2019	33,500	6/8/1953	71,500	-38,000	3/15/2019	31.5	6/21/1983	28.9	2.6
Little Sioux River at Turin, IA	3/15/2019	58,400	6/22/1996	32,000	26,400	3/15/2019	29.6	2/19/1971	27.4	2.2
Boyer River at Logan, IA	3/13/2019	35,400	6/8/2008	33,600	1,800	3/13/2019	25.3	3/1/1965	25.2	0.1
NF Elkhorn River nr Pierce, NE	3/14/2019	79,000[p]	2/19/1971	15,200	63,800	3/14/2019	17.3	2/19/1971	15.1	2.2
Elkhorn River at Waterloo, NE	3/16/2019	117,000[p]	6/12/1944	100,000	17,000	3/16/2019	24.7	3/29/1962	19.1	5.6
Platte River at Ashland, NE	3/16/2019	215,000[p]	3/10/1993	130,000	85,000	3/16/2019	24.4	2/20/1997	23.1	1.3
Platte River at Louisville, NE	3/16/2019	250,000[p]	7/25/1993	160,000	90,000	3/16/2019	13.9	3/30/1960	12.5	1.4
Missouri River at Plattsmouth, NE	3/16/2019	n/a	n/a	n/a	n/a	3/16/2019	40.6	6/30/2011	36.7	3.9
Missouri River at Nebraska City, NE	3/16/2019	342,000	4/19/1952	414,000	-72,000	3/16/2019	30.1	6/28/2011	28.3	1.8
Missouri River at Rulo, NE	3/20/2019	339,000	4/22/1952	358,000	-19,000	3/20/2019	28.1	6/27/2011	27.3	0.8
Missouri River at St. Joseph, MO	3/22/2019	317,000	4/23/1952	397,000	-80,000	3/22/2019	32.1	7/26/1993	32.1	0.0
Missouri River at Waverly, MO	3/26/2019	294,000	7/27/1993	633,000	-339,000	3/26/2019	31.6	7/27/1993	31.2	0.4
	6/1/2019	328,000			-305,000	6/1/2019	31.9			0.7

USGS – US Geological Survey (USGS) data is from the National Water Information System (NWIS) database.
Numbers highlighted in red text indicate the 2019 observed peak exceeded the record peak.
[p] 2019 USGS data is provisional.

Plate 3

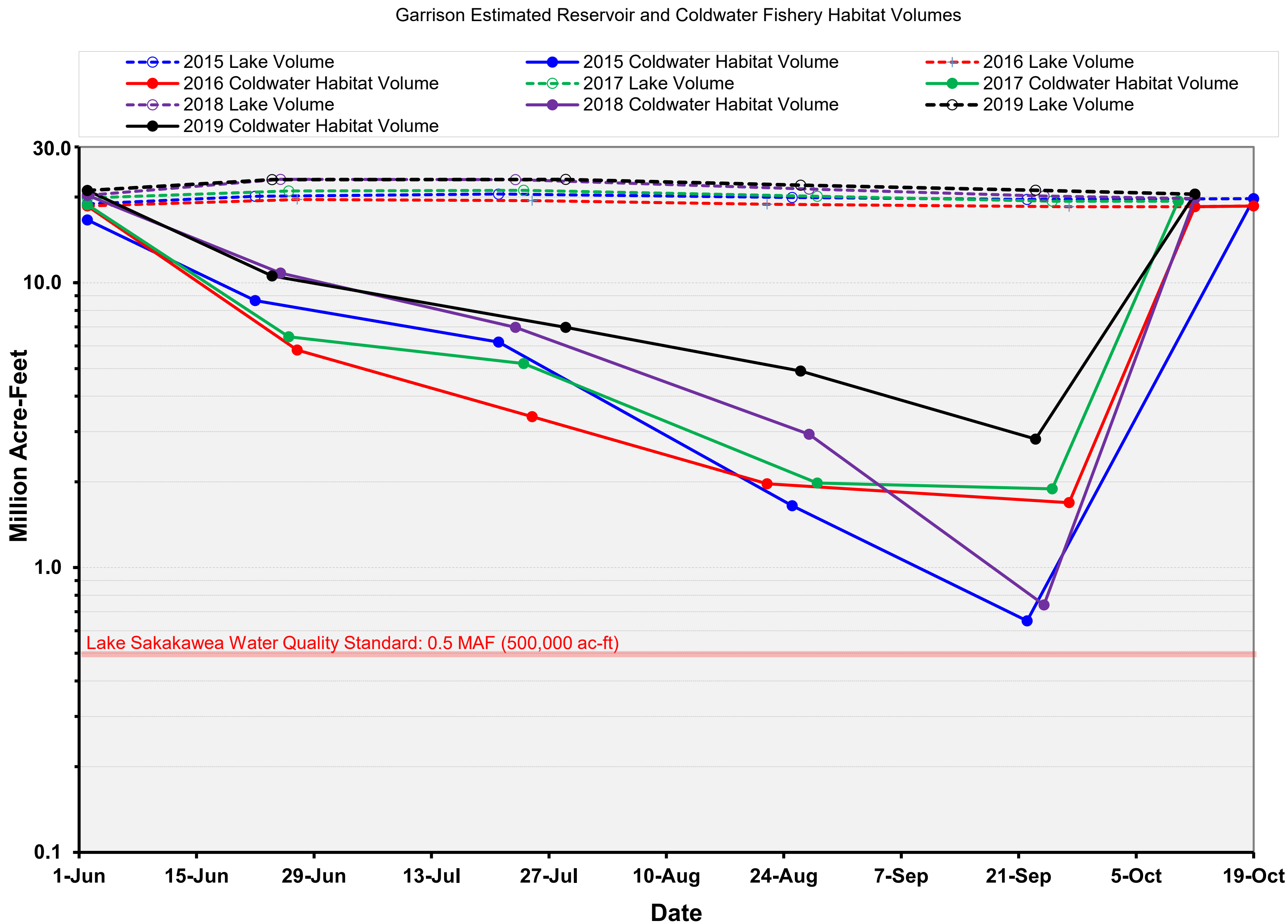

Garrison Estimated Reservoir and Coldwater Fishery Habitat Volumes
2015 Lake Volume
2015 Coldwater Habitat Volume
2016 Lake Volume
2016 Coldwater Habitat Volume
2017 Lake Volume
2017 Coldwater Habitat Volume
2018 Lake Volume
2018 Coldwater Habitat Volume
2019 Lake Volume
2019 Coldwater Habitat Volume
30.0
10.0
1.0
0.1
Million Acre-Feet
Lake Sakakawea Water Quality Standard: 0.5 MAF (500,000 ac-ft)
1-Jun
15-Jun
29-Jun
13-Jul
27-Jul
10-Aug
24-Aug
7-Sep
21-Sep
5-Oct
19-Oct
Date

Plate 4

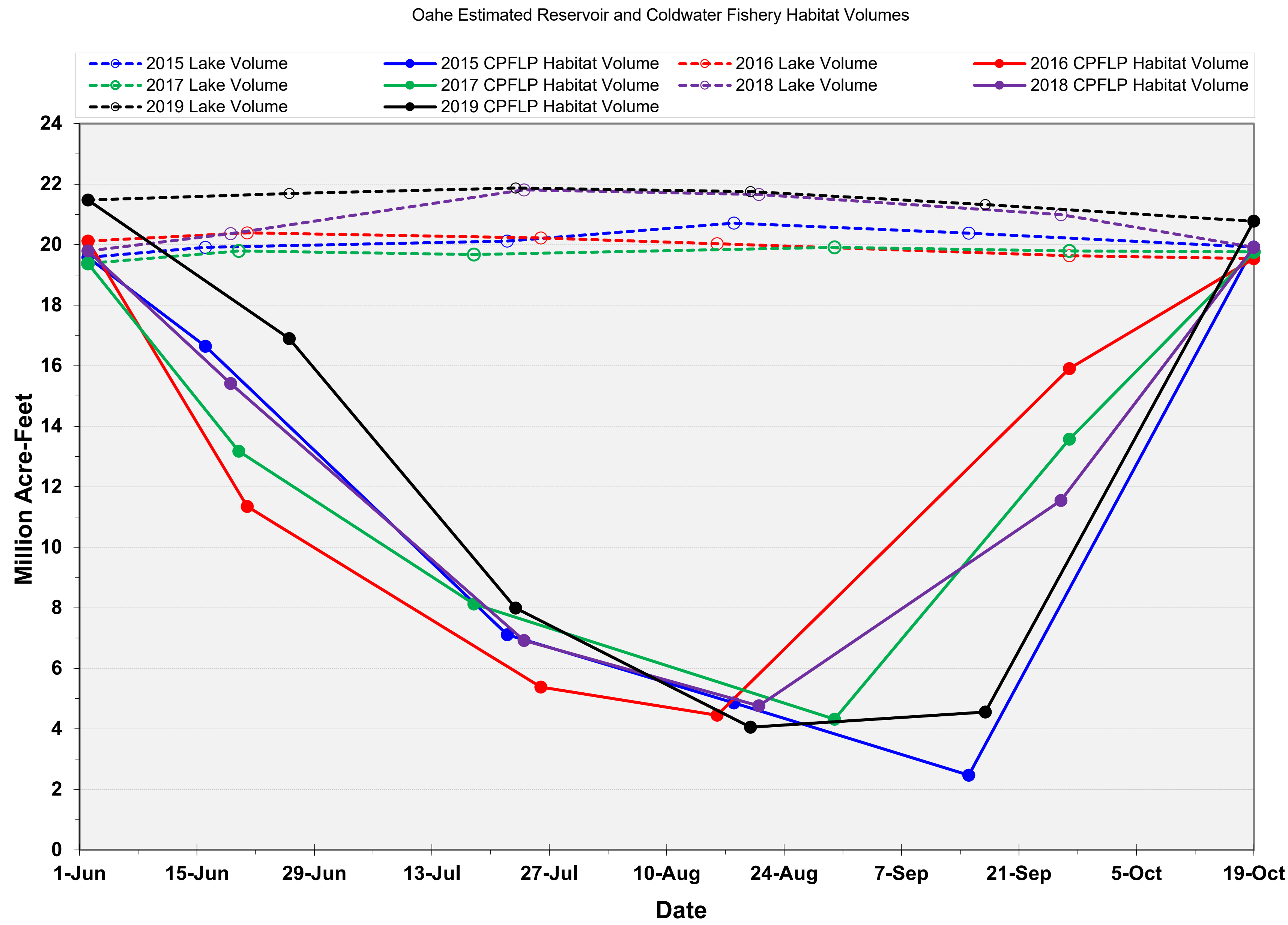

Oahe Estimated Reservoir and Coldwater Fishery Habitat Volumes
2015 Lake Volume
2015 CPFLP Habitat Volume
2016 Lake Volume
2016 CPFLP Habitat Volume
2017 Lake Volume
2017 CPFLP Habitat Volume
2018 Lake Volume
2018 CPFLP Habitat Volume
2019 Lake Volume
2019 CPFLP Habitat Volume
Million Acre-Feet
0
2
4
6
8
10
12
14
16
18
20
22
24
1-Jun
15-Jun
29-Jun
13-Jul
27-Jul
10-Aug
24-Aug
7-Sep
21-Sep
5-Oct
19-Oct
Date

Plate 5