Upper Missouri River Basin
January 2019 Calendar Year Runoff Forecast
January 8, 2019

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

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

The December runoff summation for the upper Basin above Sioux City was 213% of average. The December runoff summation for the upper Basin above Gavins Point was 192% of average. Runoff was well-above average in every reach except Fort Randall and Gavins Point. The first three weeks of December experienced warmer-than-normal temperatures, but gave way to much colder temperatures the last week.

Looking back at 2018, the calendar year runoff summation for the upper Basin was **41.9 MAF**, which is **165% of average**. Upper basin runoff in 2018 was the 3rd highest in 120 years of record following only 2011 and 1997. The 2018 runoff was caused by heavy plains snowpack in Montana, well-above-average mountain snowpack and large areas of above-normal precipitation.

2019 Calendar Year Forecast Synopsis

The 2019 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA, updated on January 2, is **25.7 MAF (101% of average).** The 2019 calendar year runoff forecast above Gavins Point Dam is **22.2 MAF (96% of average)**.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 12 months, expected inflow could range from the 35.8 MAF upper basic forecast to the 16.9 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that twelve months are being forecast for this January 1 forecast (0 months observed/12 months forecast), the range of possible wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is very large, and is attributed to all 6 reaches for the entire year. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for January 1, 2019 is shown in **Figure 1**. The drought monitor is available at http://droughtmonitor.unl.edu/. The U.S. Drought Monitor shows only Abnormally Dry (D0) conditions in a few small areas of the Missouri River Basin. Most of the D1 Moderate Drought area in North Dakota is outside the Basin. The Seasonal Drought Outlook in **Figure 2**, which extends through the end of March, indicates that drought conditions are likely to persist in northern North Dakota, and no drought conditions are likely to develop anywhere in the Basin.

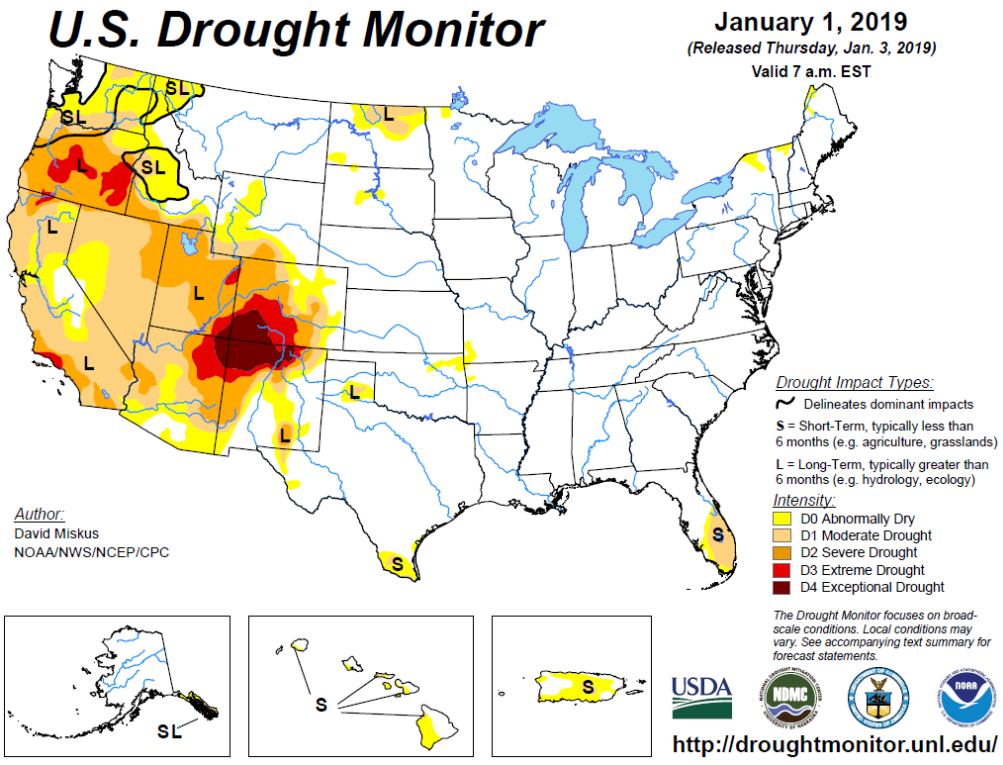

Figure 1. National Drought Mitigation Center U.S. Drought Monitor for January 1, 2019.

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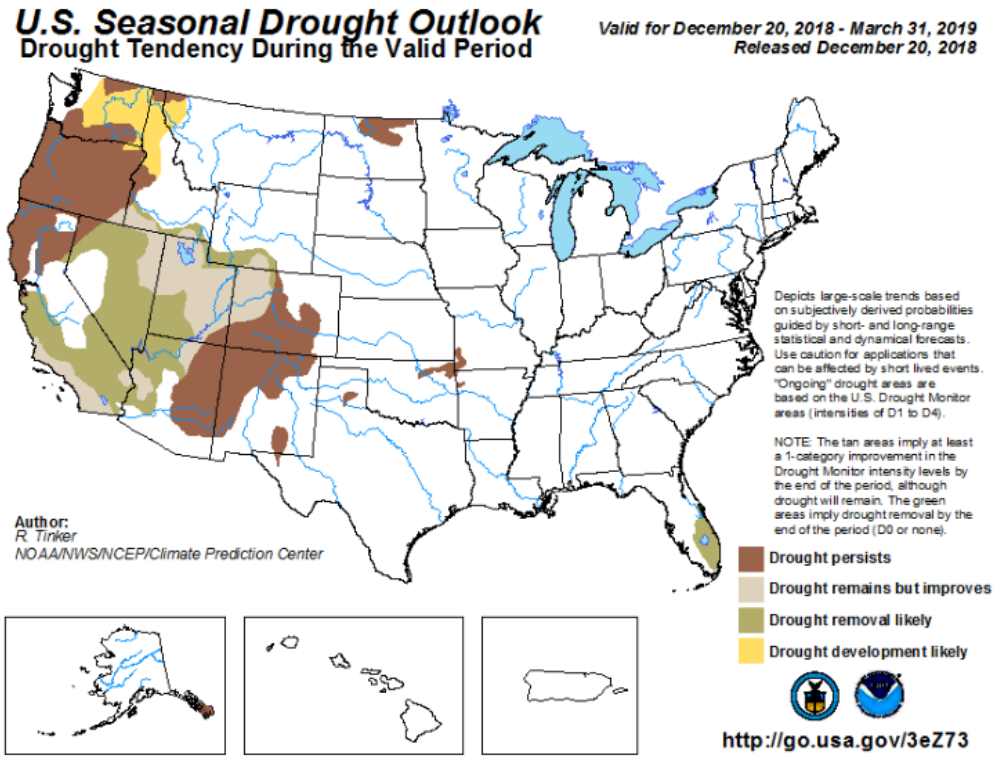

Figure 2. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. The December precipitation accumulations are shown in **Figure 3** as inches of precipitation (left) and percent of normal precipitation (right). December precipitation was more than 200% of average in areas of Montana, Wyoming, the Dakotas, Nebraska, Iowa, and Kansas. In contrast, December precipitation was below normal in western Montana and Wyoming. It was also less than 5% of average in northeastern Colorado.

October-November-December precipitation accumulations are shown in **Figure 4**. The three-month accumulations reflect the ongoing above-normal precipitation pattern in the lower Basin states of Nebraska, Kansas, Iowa, and Missouri, with amounts greater than 150% of average in some areas. In contrast, the Rocky Mountains have had average to below-average 3-month precipitation, resulting in mountain snowpack amounts that are below average. Precipitation in the upper Basin plains has been variable; however, there are only a few localized areas affected by long-term precipitation deficits.

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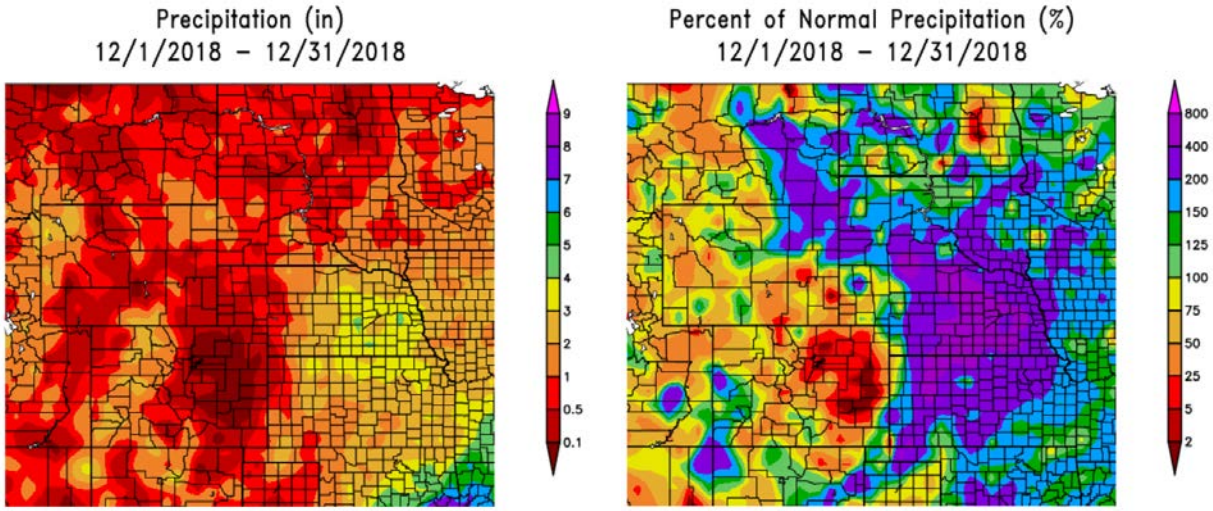


Figure 3. December 2018 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

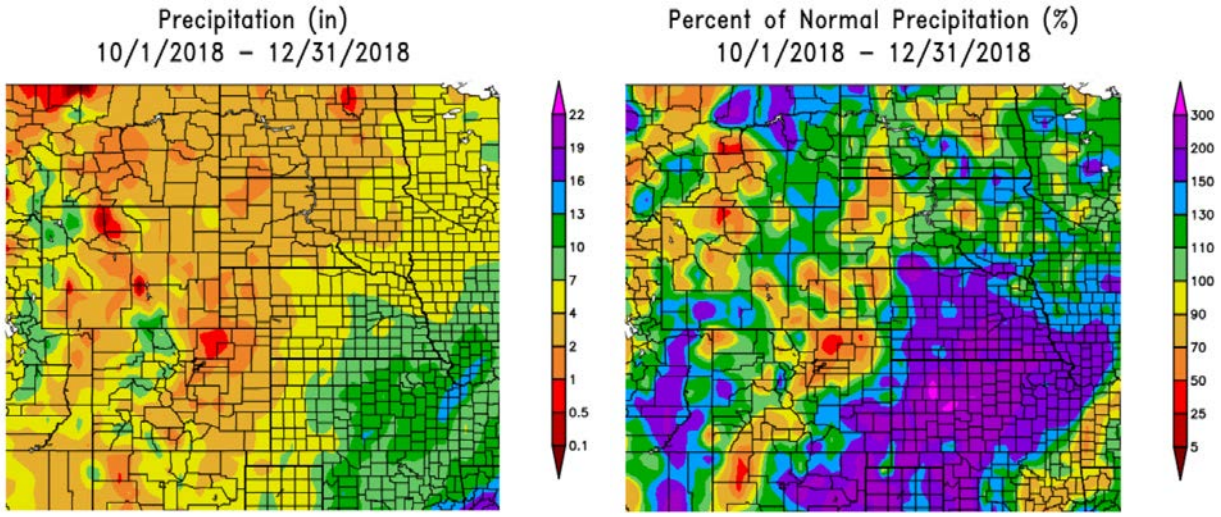


Figure 4. October-November-December 2018 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

December temperature departures in degrees Fahrenheit (deg F) in the left image of **Figure 5** indicate warmer-than-normal temperatures over all of the Basin. December temperatures in areas of Montana, North Dakota, and South Dakota were greater than 6 deg F above normal, reflecting the much warmer-than-normal temperatures during the first three weeks of December. October-November-December temperature departures, in the right image of **Figure 5**, were slightly below normal in the lower Basin, and normal to slightly above normal in the upper Basin.

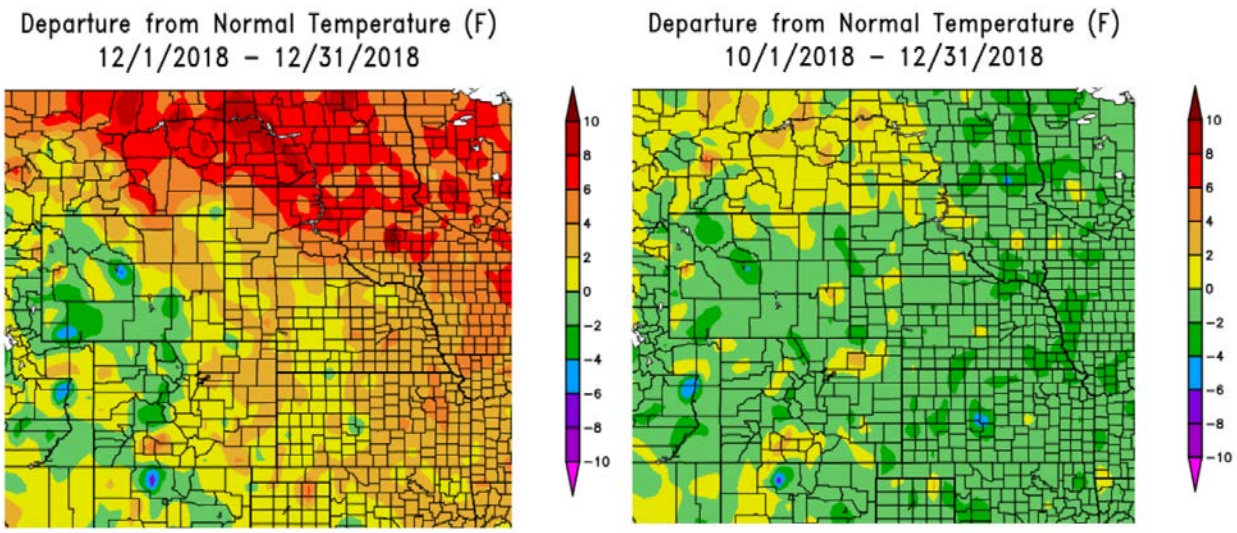
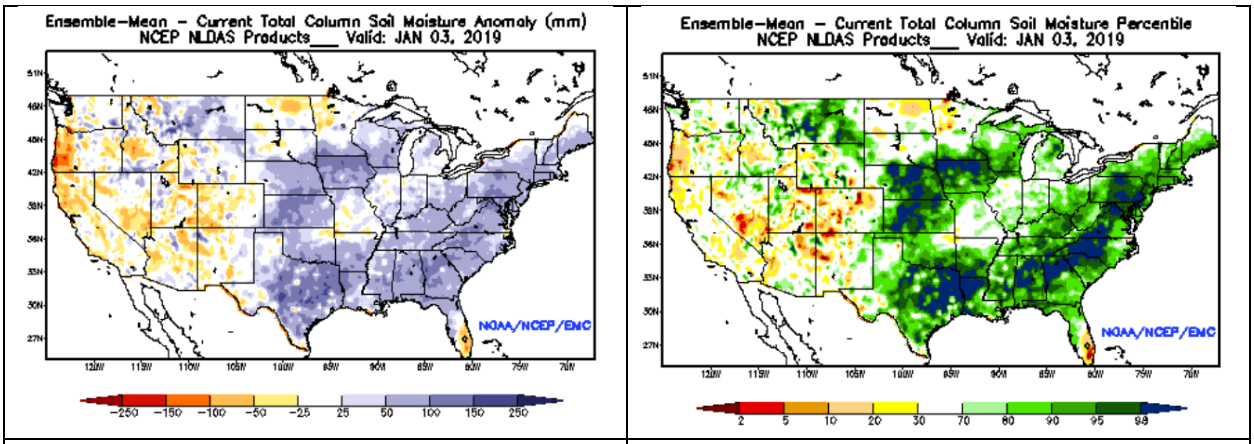


Figure 5. December 2018 and October-November-December 2018 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the soil moisture conditions will provide some insight into late winter and early spring runoff potential.

The left image of **Figure 6** shows the current NOAA NLDAS ensemble soil moisture anomaly and the right image of **Figure 6** shows the soil moisture percentile on January 3, 2019. Soil moisture anomalies and percentiles are well above normal in Montana, southern South Dakota, Nebraska, Iowa, and Kansas. Soil moisture conditions are particularly wet in Nebraska, Iowa, and Kansas, where percentiles are greater than the 95th percentile for wetness over most of the three states. Conditions are normal to slightly below normal over the rest of the Dakotas, Wyoming and Colorado. Spring runoff could potentially be above normal under normal winter precipitation and snowfall accumulations due to the above-normal soil moisture conditions in areas of the plains. Spring mountain snowpack runoff could potentially be below normal under normal winter precipitation and snowfall accumulations where soil moisture conditions are below normal.



Soil Moisture Anomaly (mm)	Soil Moisture Percentile

Figure 6. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Plains Snowpack

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. A common misperception is that the March-April runoff is a result of plains snowmelt only. Historically, about 25% of annual runoff occurs in March and April, during the time when plains snow is melting, due to both melting snowpack and rainfall runoff. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more than a week in advance. Thus, the March-April runoff forecast is formulated based on existing plains snowpack and existing basin conditions and hydrologic forecasts, which for this year primarily includes long-term precipitation outlooks. At this time of year, plains snowpack provides some indication of March-April runoff; however, as the snowpack reaches its ultimate peak accumulation, better forecasts of future runoff can be made. Some areas of North Dakota have received a significant amount of snowfall so far this winter.

The National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC), modeled snow assessment from January 1, shown in **Figure 7**, indicates 1 to 3 inches of snow water equivalent (SWE) have accumulated in sparse areas of the eastern Dakotas and Nebraska. Only trace amounts of SWE are present across most of the Basin. At this time, plains snowpack is considered "light" based on criteria described in the MRBWM technical report *Long-Term Runoff Forecasting*.

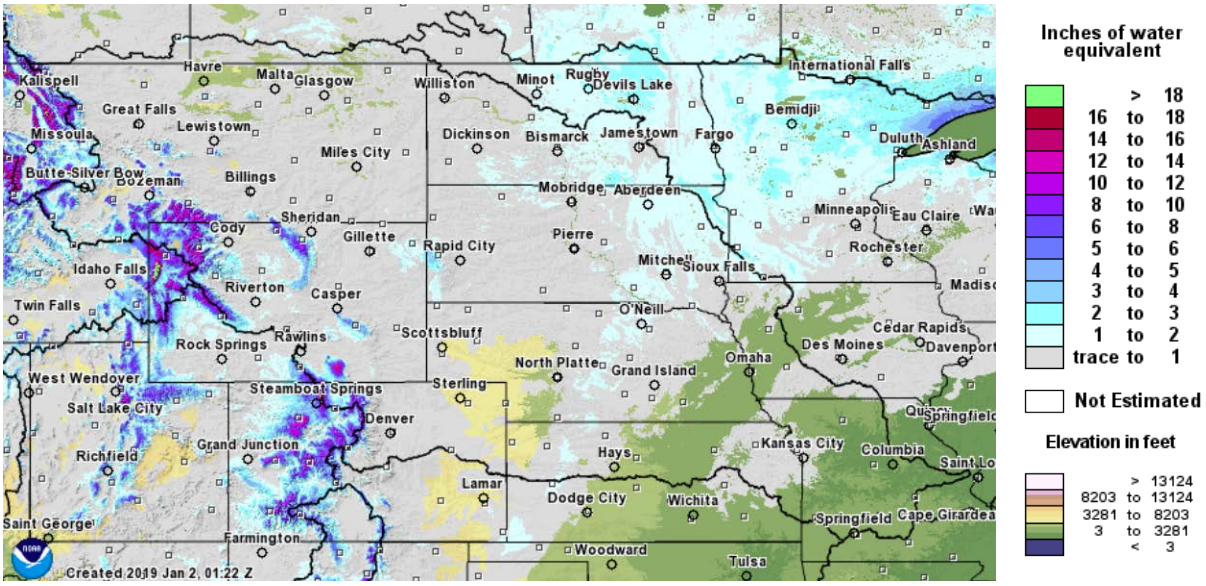


Figure 7. January 1, 2019 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reservoir reaches. It is typically NOT a factor influencing runoff at the beginning of a calendar year.

Figure 8 includes time series plots of the average mountain SWE beginning on October 1, 2018 based on the NRCS SNOTEL data for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of January 7, 2019, the Corps of Engineers computed an average mountain SWE in the Fort Peck reservoir reach of 6.3 inches, which is 79% of average based on the 1981-2010 average SWE for the Fort Peck reach. In the reservoir reach between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 5.8 inches, which is 82% of average based on the 1981-2010 average SWE for the Garrison reach. Typically by January 1, 44% of the total accumulation has occurred.

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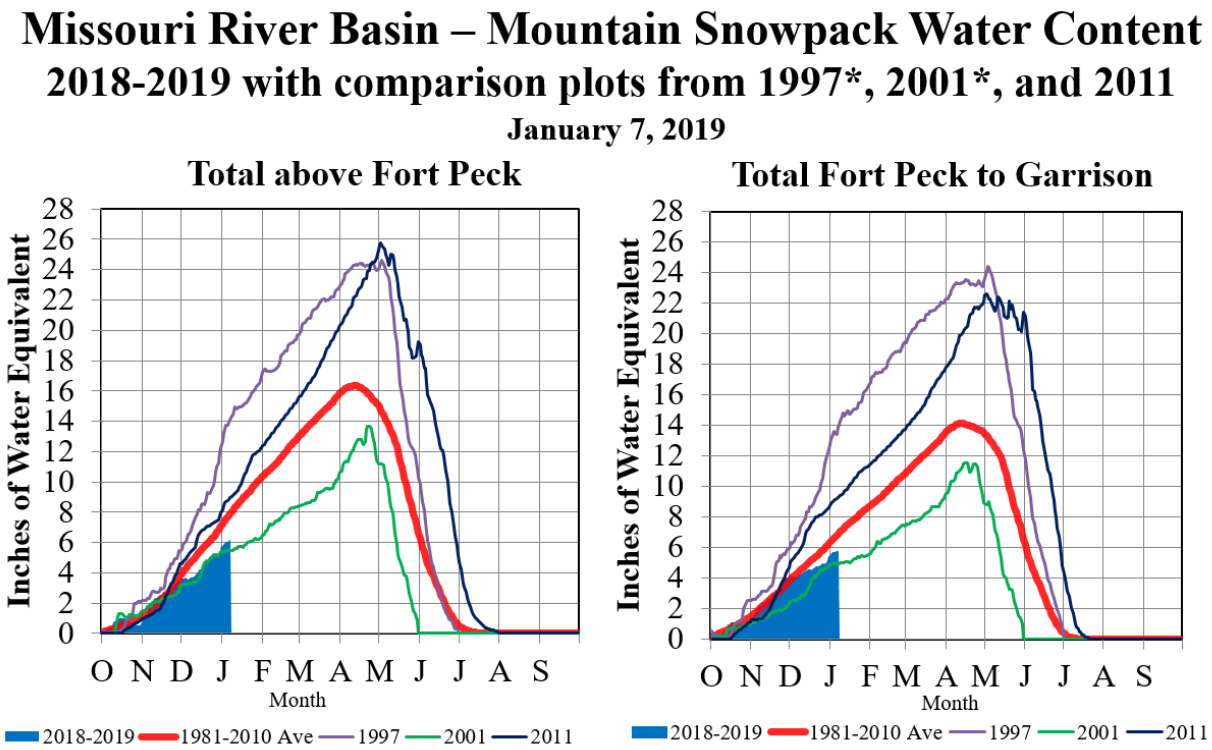

Figure 8. Mountain snowpack water content on January 7, 2019 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO Outlook indicates that neutral conditions are present, but there is a 90% chance that El Niño conditions will develop and continue through the Northern Hemisphere this winter. During an El Niño phase of ENSO, there are increased probabilities for above-normal temperatures in the upper Missouri Basin during the winter season.

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Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

The CPC temperature outlook through January 21 (**Figure 9**) indicates increased chances for above-normal temperatures over the Basin, potentially inhibiting formation of mountain and plains snowpack. The precipitation outlook indicates increased chances for below-normal precipitation over Montana and North Dakota, with increased chances for above-normal precipitation over the rest of the Basin.

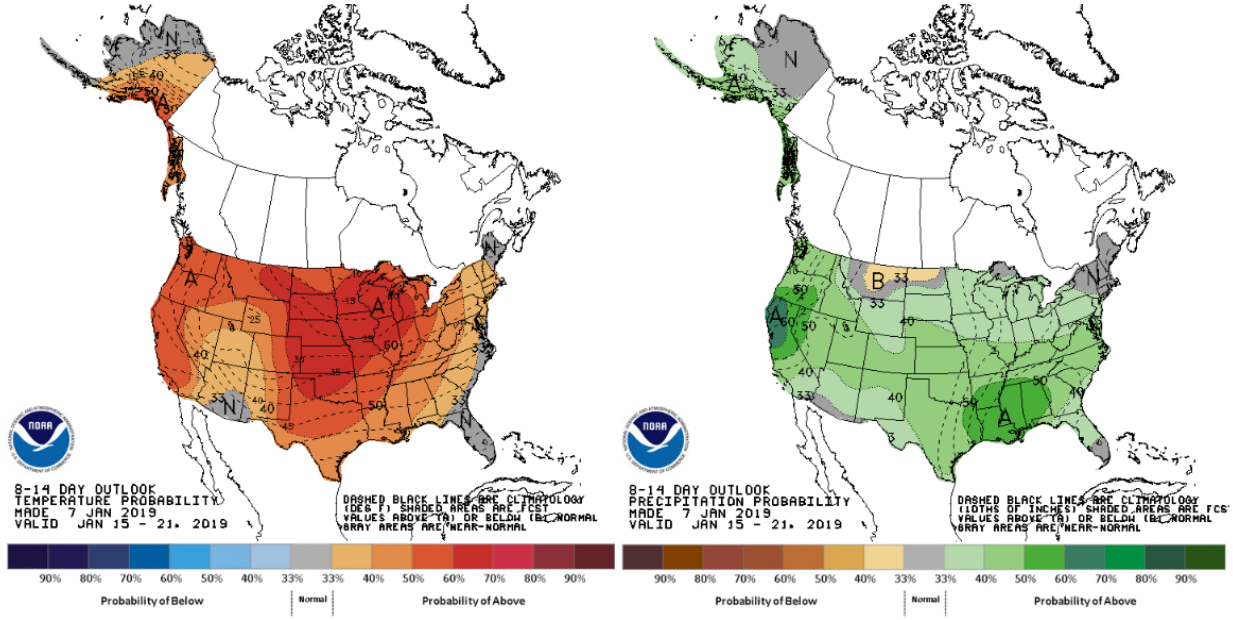

Figure 9. CPC 8-14 Day temperature and precipitation outlooks through January 21, 2019.

The January CPC outlooks in **Figure 10** indicate increased chances for above-normal temperatures in most of the Basin and equal chances in portions of Kansas and Missouri. With regard to precipitation, the January outlook indicates increased chances for below-normal precipitation over most of the Basin with areas of equal chances in Kansas and Missouri.

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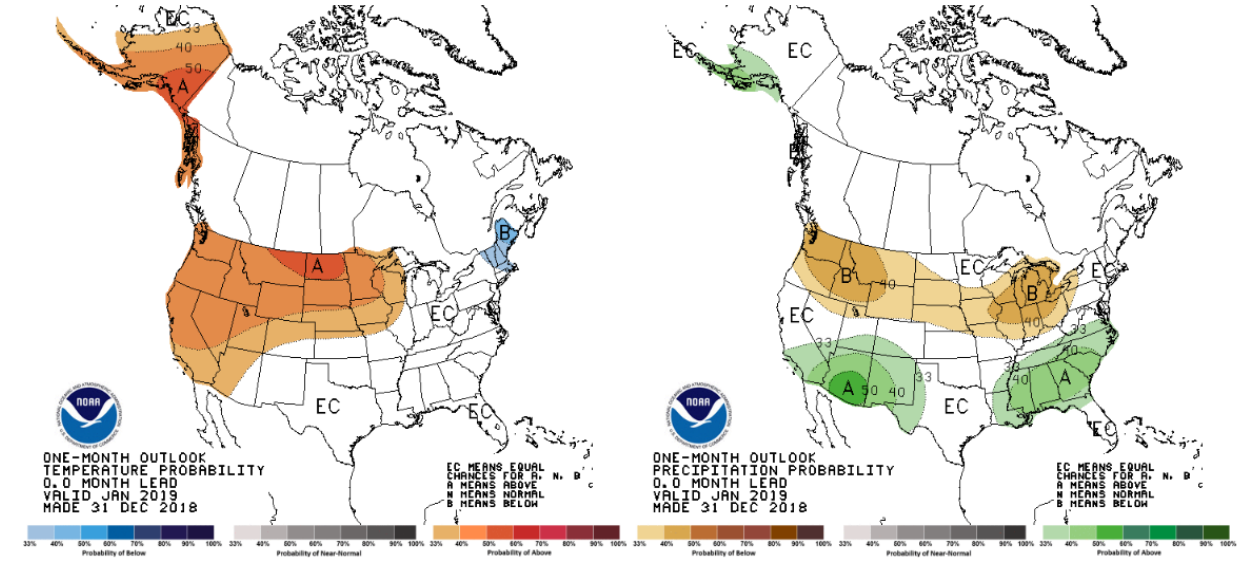

Figure 10. CPC January 2019 temperature and precipitation outlooks.

During the February-March-April 2019 period, the CPC outlooks in **Figure 11** indicate increased chances for above-normal temperatures in Montana, Wyoming, and the Dakotas consistent with El Niño conditions. With regard to the precipitation outlook, El Niño could increase chances for above-normal precipitation in the lower Basin and southern Rockies. There are equal chances for precipitation in Montana, Wyoming, the Dakotas, and Iowa.

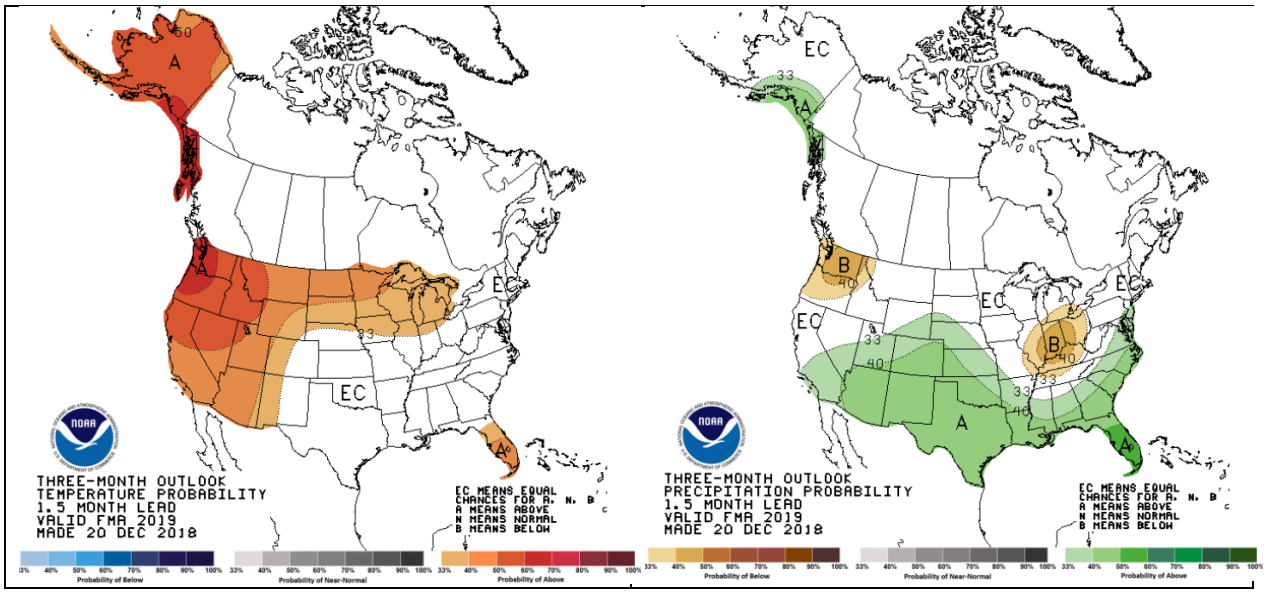

Figure 7. CPC February-March-April 2019 temperature and precipitation outlooks.

During the May-June-July 2019 period, CPC outlooks in **Figure 12** indicate equal chances for above-normal, below-normal, and normal temperatures in much of the upper Basin. There is a slight increase in the chances for above-normal temperatures in western Montana and western Wyoming, Colorado, Kansas, and Missouri. The precipitation outlook indicates a slight increase

in chances for above-normal precipitation over the Basin, with the exception of Montana and Missouri.

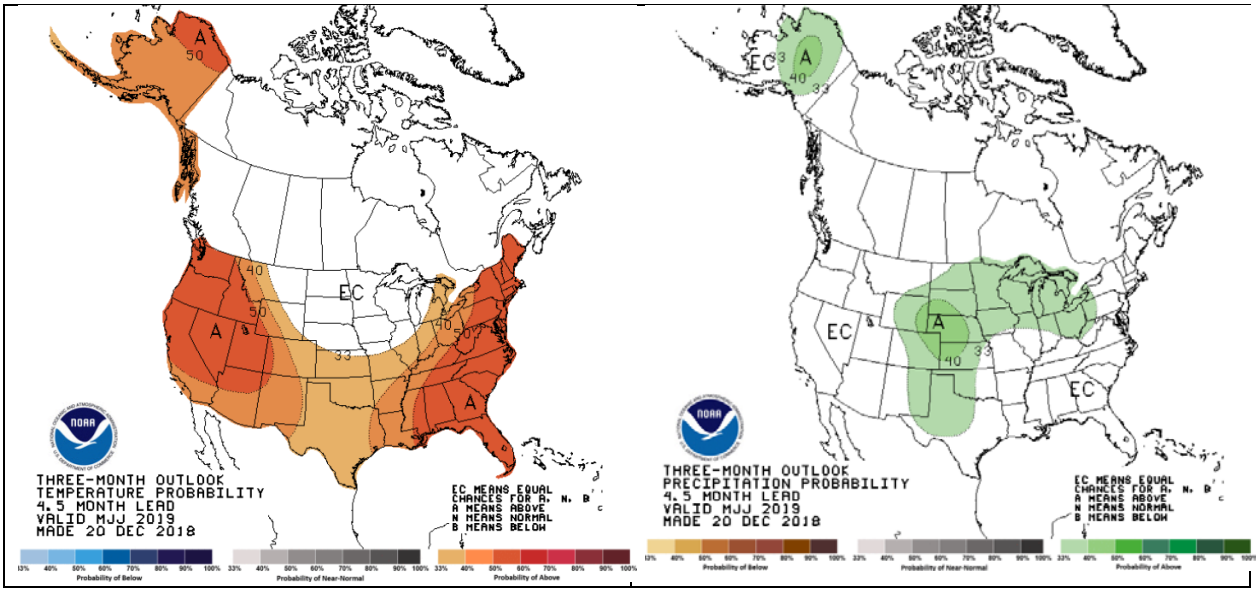

Figure 12. CPC May-June-July 2019 temperature and precipitation outlooks.

During the August-September-October 2019 period, CPC outlooks in **Figure 13** indicate slight increases in the chances for above-normal temperatures, and equal chances for precipitation. The precipitation outlook is reflected in the average runoff forecast for August, September, and October of 2019.

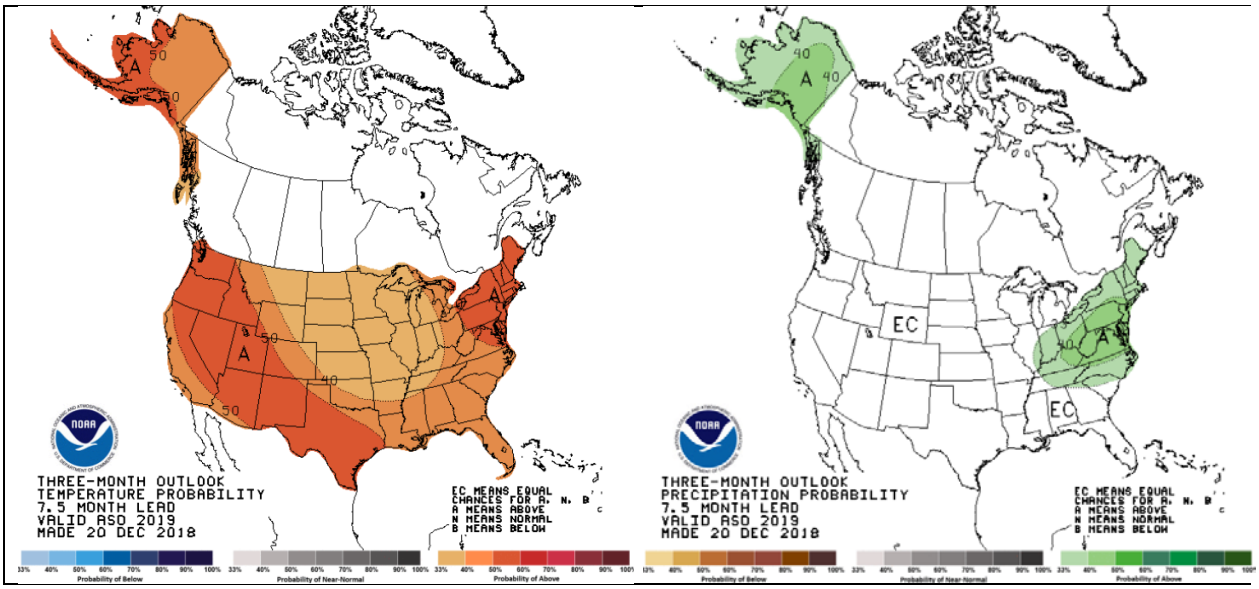

Figure 13. CPC August-September-October 2019 temperature and precipitation outlooks.

During the November 2019-December 2019-January 2020 period, CPC outlooks in **Figure 14** also indicate slight increases in the chances for above-normal temperatures, and equal chances

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for precipitation. The precipitation outlook is reflected in the average runoff forecast for the end of 2019.

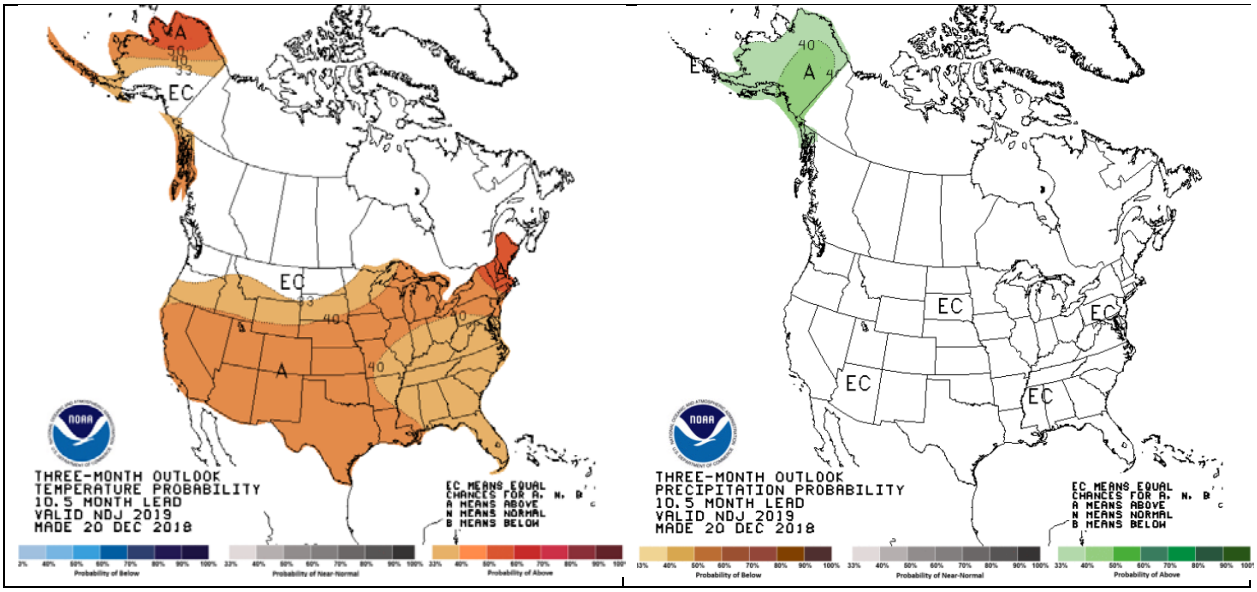

Figure 14. CPC November 2019-December 2019-January 2020 temperature and precipitation outlooks.

Summary

In summary, the 2019 calendar year runoff forecast is **25.7 MAF, 101%** of average. For the beginning of the year, above-normal runoff is forecast to continue for all reaches. Below-normal runoff is forecasted for the Fort Peck and Garrison reaches from March through July due to the below-average plains and mountain snowpack. The Sioux City reach is forecast to remain above-normal throughout the year, based on wet soil moisture conditions and past years. About normal runoff conditions are forecasted for the remainder of the Basin through the rest of the year.

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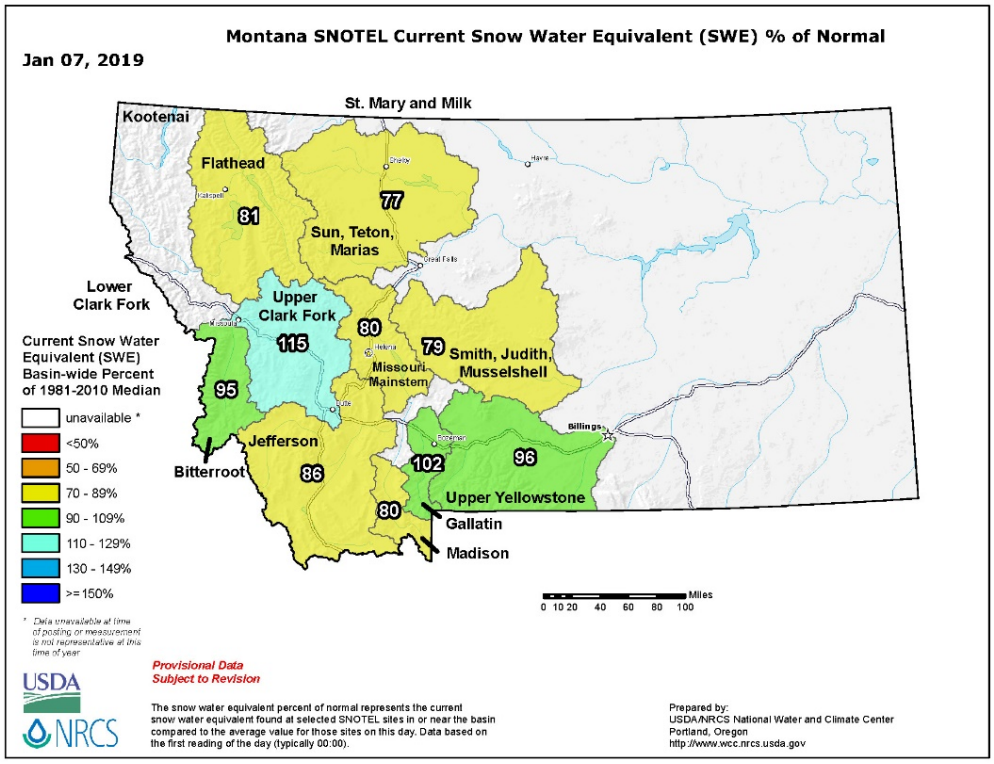
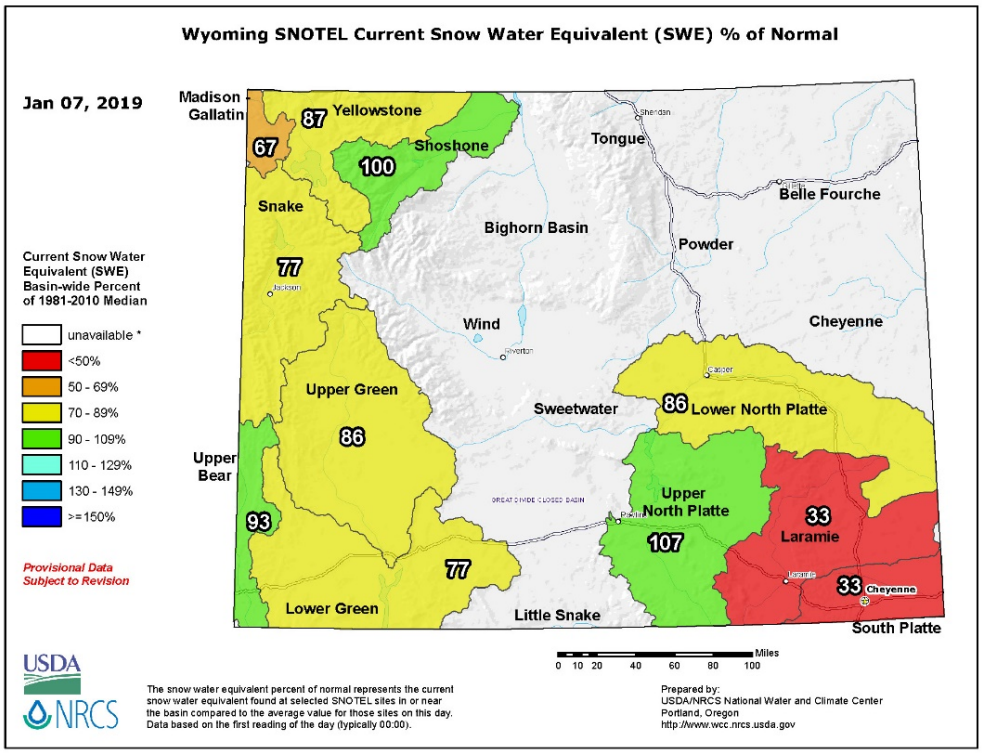
Additional Figures





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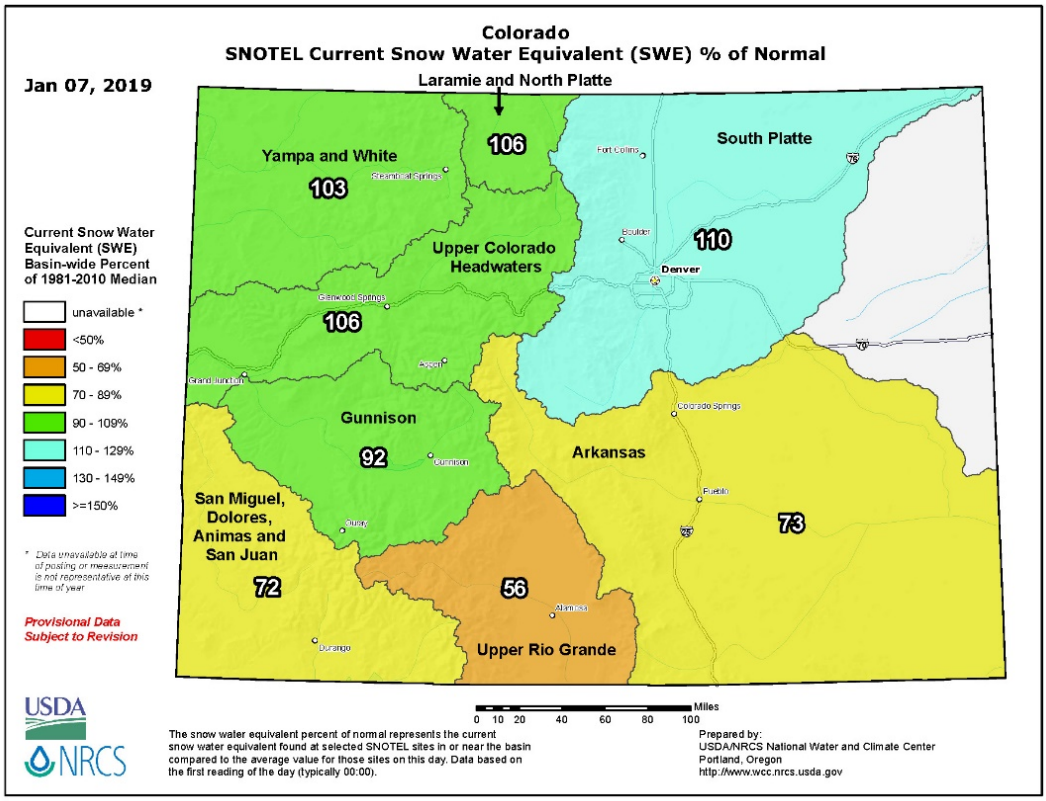
Colorado
SNOTEL Current Snow Water Equivalent (SWE) % of Normal
Jan 07, 2019
Laramie and North Platte
Yampa and White
103
106
South Platte
110
Upper Colorado Headwaters
106
Gunnison
92
Arkansas
73
San Miguel, Dolores, Animas and San Juan
72
56
Upper Rio Grande
Fort Collins
Steamboat Springs
Boulder
Denver
Glenwood Springs
Aspen
Grand Junction
Colorado Springs
Gunnison
Pueblo
Ouray
Alamosa
Durango
Current Snow Water Equivalent (SWE) Basin-wide Percent of 1981-2010 Median
unavailable *
<50%
50 - 69%
70 - 89%
90 - 109%
110 - 129%
130 - 149%
>=150%
* Data unavailable at time of posting or measurement is not representative at this time of year
Provisional Data Subject to Revision
0 10 20 40 60 80 100
Miles
The snow water equivalent percent of normal represents the current snow water equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).
Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

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Upper Missouri River Basin
February 2019 Calendar Year Runoff Forecast
February 7, 2019

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

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

The January runoff summation for the upper Basin above Sioux City was 0.9 MAF, 110 percent of average, largely due to above average runoff in the Gavins Point and Sioux City reaches. The January runoff summation for the basin above Gavins Point was 82 percent of average, while runoff was over 400 percent of average in the Sioux City reach. Runoff was well-below average in the Garrison, Oahe and Fort Randall reaches.

2019 Calendar Year Forecast Synopsis

The 2019 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA, updated on January 2, is **25.6 MAF**, 0.3 MAF above average. The 2019 calendar year runoff forecast above Gavins Point Dam is **21.9 MAF**, slightly less than average.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 11 months, expected inflow could range from the **35.4 MAF** upper basic forecast to the **16.9 MAF** lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to “bracket” the range of expected runoff given much wetter or drier conditions, respectively. Given that eleven months are being forecast for this February 1 forecast

(1 month observed/11 months forecast), the range of possible wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is very large, and is attributed to all 6 reaches for the entire year. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for February 5, 2019 is shown in **Figure 1**. The drought monitor is available at http://droughtmonitor.unl.edu/.

The Drought Monitor shows some areas of Abnormal Dryness (D0) present in the Bighorn Basin of Wyoming and the upper Yellowstone and Missouri Basins in northwestern Wyoming and southwestern Montana. There are also some patches of Abnormal Dryness in north central and southwestern North Dakota and central South Dakota. No drought conditions are present anywhere else in the Missouri Basin.

The Seasonal Drought Outlook in **Figure 2**, which extends through the end of April, indicates there is likely to be no change to the few abnormally dry conditions in the Basin.

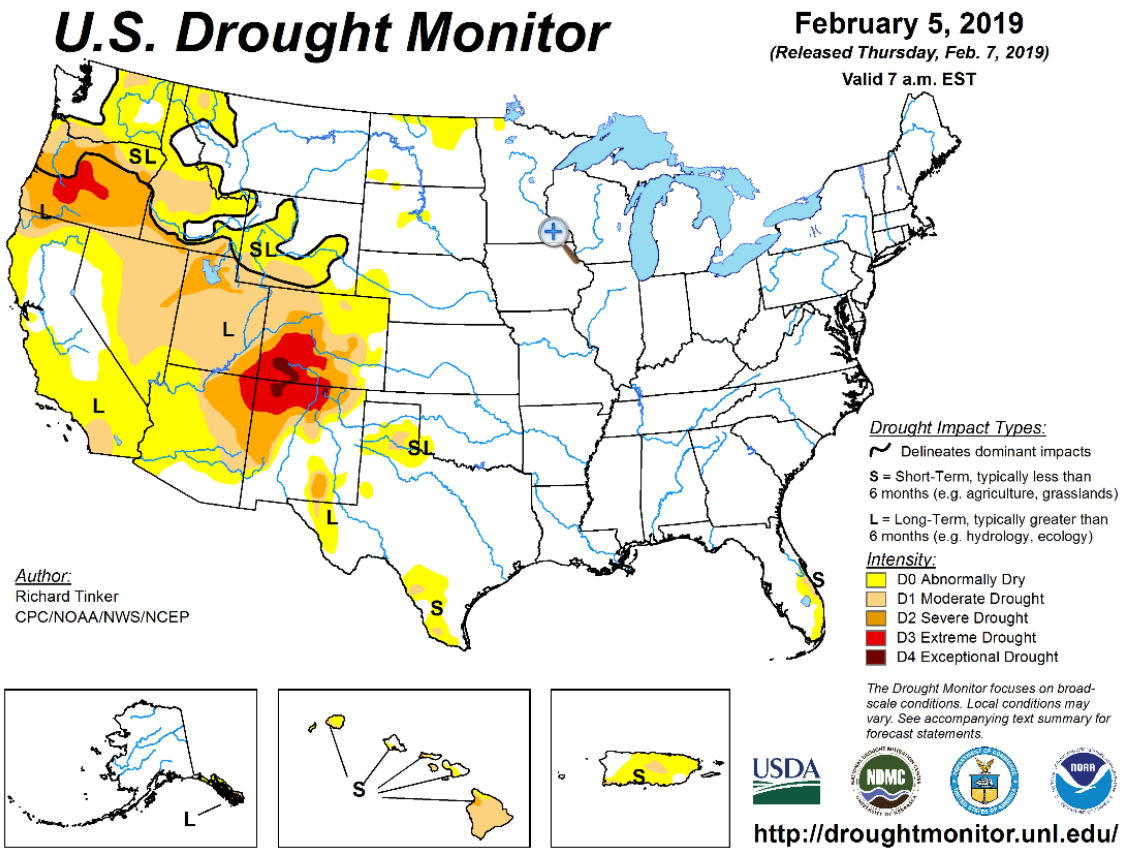


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for January 29, 2019.

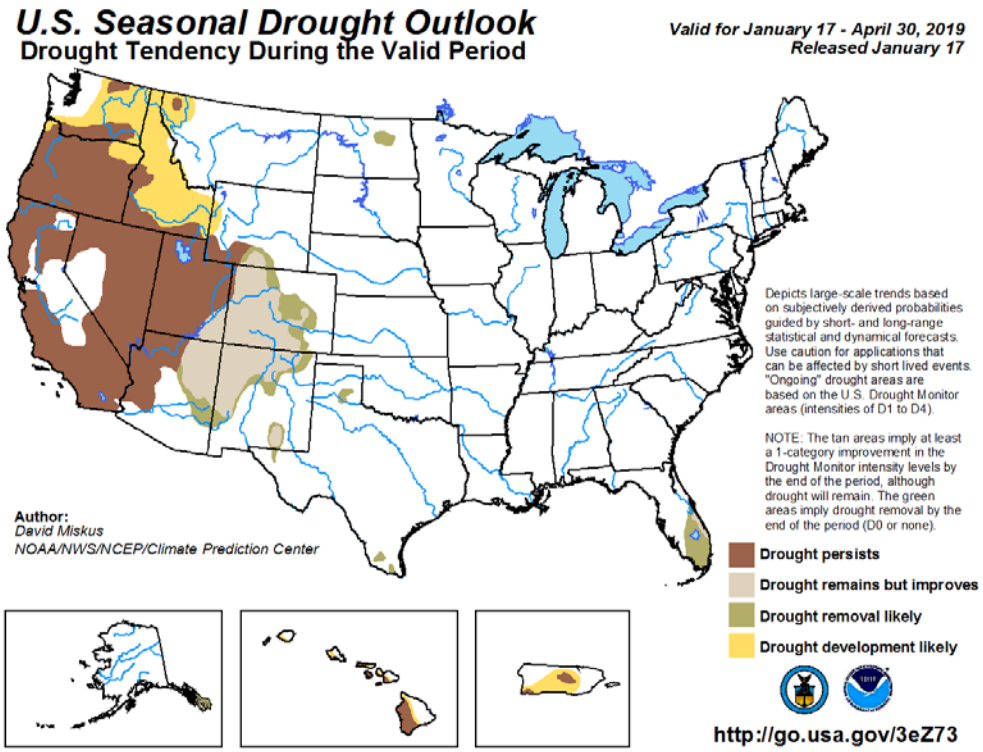


Figure 2. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. The January precipitation accumulations are shown in **Figure 3** as inches of precipitation (left) and percent of normal precipitation (right). January precipitation was variable over the upper Basin. The storm track in January generally extended from western Montana into southwestern Minnesota. It produced areas of above-normal precipitation in Montana and the Dakotas. In Nebraska, southeastern South Dakota and Iowa, precipitation was less than 50 percent of normal. In contrast, much of the lower Basin below Omaha received well-above-normal precipitation from two winter storms that occurred on January 11-13 and January 22-23.

Snowfall precipitation totals in January were varied across the Missouri Basin (see **Table 1**). Great Falls, Billings and Bismarck all received above-normal snowfall, while Glasgow in northern Montana received well-below-normal snowfall. Snowfall in central and eastern South Dakota was about normal. However, eastward into Minnesota, Worthington received 18 inches, compared to a 7-inch January normal. Snowfall in the lower basin was above normal, highlighted by a 20-inch total in Nebraska City, compared to a 6.5-inch normal, and 13.5 inches in Maryville, MO compared to a 3.2-inch normal.

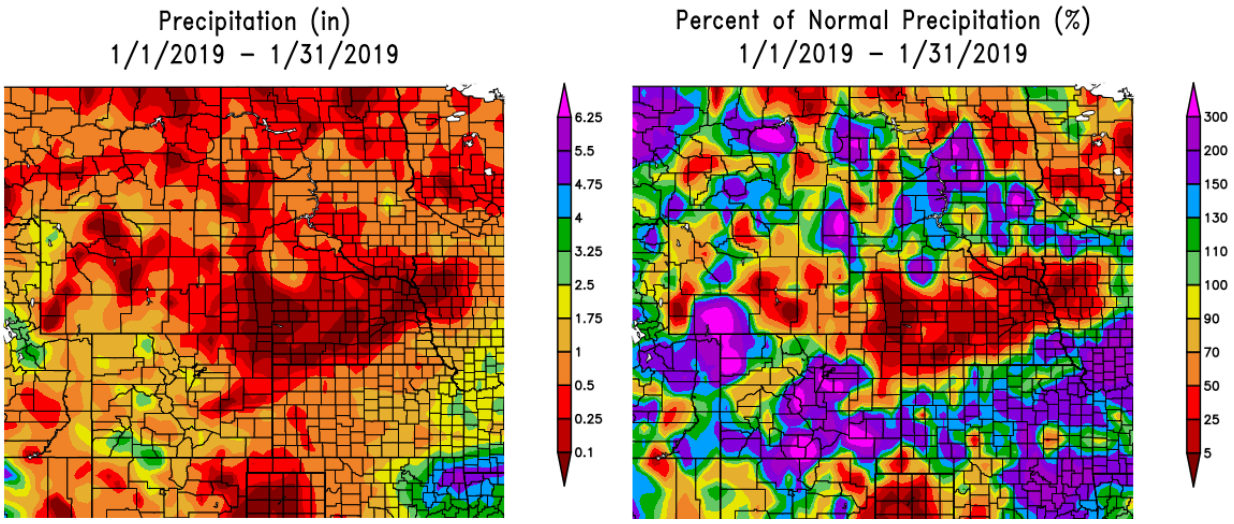


Figure 3. January 2019 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 1. January 2019 snowfall totals compared to normal January totals.

Location	January Snowfall inches	Normal Snowfall inches
Great Falls, MT	15.1	8.6
Glasgow, MT	3.7	8.0
Billings, MT	13.7	8.4
Bismarck, ND	11.3	8.9
Chamberlain, SD	8.0	6.4
Aberdeen, SD	12.7	6.4
Webster, SD	8.9	11.6
Sioux Falls, SD	8.1	7.7
Worthington, MN	18.0	7.0
Sioux City, IA	1.7	6.7
Omaha, NE	12.9	6.1
Lincoln, NE	9.7	6.4
Nebraska City, NE	20.0	6.5
Maryville, MO	13.5	3.2
Washington, KS	11.6	4.6
Kansas City, MO	9.3	4.6

November-December-January precipitation accumulations, shown in **Figure 4**, reveal the above-normal precipitation accumulations extending from eastern Montana into Nebraska and Kansas. This pattern is mostly influenced by December and January precipitation totals in the lower Basin, which were well-above average.

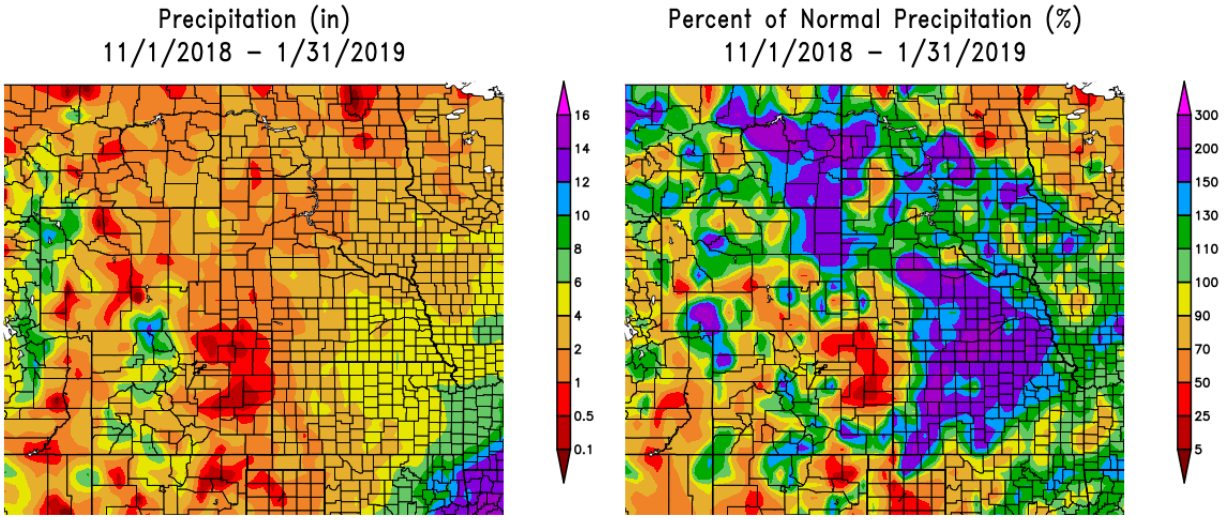


Figure 4. November-December 2018-January 2019 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

January temperature departures in degrees Fahrenheit (deg F) in the left image of **Figure 5** indicate warmer-than-normal temperatures over the upper Basin west of the Missouri River. Temperatures were 4 to 8 deg F above normal in northern and eastern Montana. Above-normal temperatures extended southward through the western Dakotas and Nebraska. Temperatures were below normal east of the Missouri River in the Dakotas. The coldest temperatures occurred at the end of January, and contributed to monthly departures that were 4 to 8 deg F below normal in northeastern South Dakota. November-December-January temperature departures, shown in the right image of **Figure 5**, were above normal for much of the upper Basin. The greatest departures from normal have ranged from 2 to 6 deg F above normal over much of Montana.

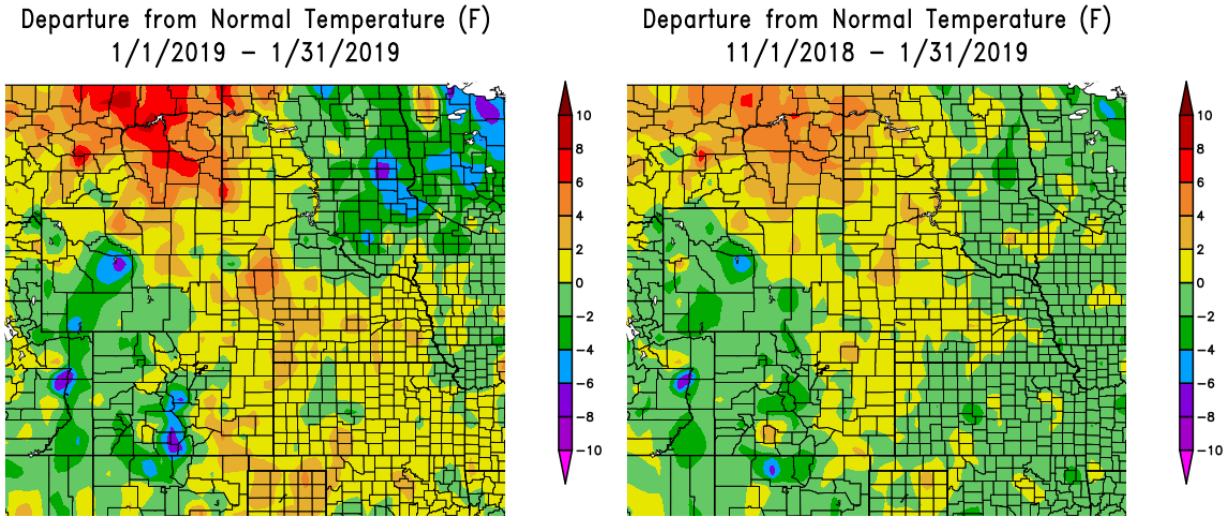
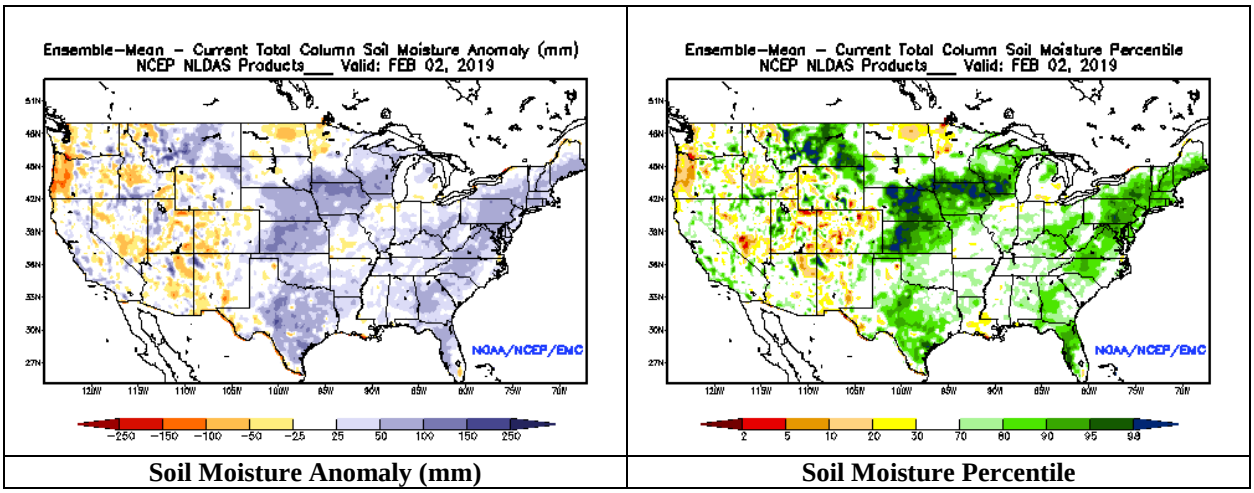


Figure 5. January 201 and November-December 2018-January 2019 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the soil moisture conditions will provide some insight into late winter and early spring runoff potential.

The left image of **Figure 6** shows the current NOAA NLDAS ensemble soil moisture anomaly and the right image of **Figure 6** shows the soil moisture percentile on February 2, 2019. Soil moisture anomalies and percentiles are well-above normal in Montana, northeastern Wyoming, southern South Dakota, Nebraska, Iowa, and Kansas. Soil moisture conditions are particularly wet in Nebraska, Iowa, and Kansas, where percentiles are greater than the 95th percentile for wetness over most of the three states. Conditions are normal to slightly below normal over the rest of the Dakotas, Wyoming and Colorado. Spring runoff could potentially be above normal under normal winter precipitation and snowfall accumulations due to the above-normal soil moisture conditions in areas of the plains. Spring mountain snowpack runoff could potentially be below normal with average winter precipitation and snowfall accumulations where soil moisture conditions are below normal.



Soil Moisture Anomaly (mm)	Soil Moisture Percentile

Figure 6. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Plains Snowpack

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. A common misperception is that the March-April runoff is a result of plains snowmelt only. Historically, about 25% of annual runoff occurs in March and April, during the time when plains snow is melting, due to both melting snowpack and rainfall runoff. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more

than a week in advance. Thus, the March-April runoff forecast is formulated based on existing plains snowpack and existing basin conditions and hydrologic forecasts, which for this year primarily includes long-term precipitation outlooks. At this time of year, plains snowpack provides some indication of March-April runoff; however, as the snowpack reaches its ultimate peak accumulation, better forecasts of future runoff can be made. Some areas of North and South Dakota have received a significant amount of snowfall so far this winter.

The National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC), modeled snow assessment from February 6, shown in **Figure 7**, indicated 2 to 4 inches of snow water equivalent (SWE) have accumulated in areas of the eastern Dakotas, and more than 4 inches in some localized areas. At this time, plains snowpack is considered *moderate* to *heavy* in the Sioux City reach based on criteria described in the MRBWM technical report *Long-Term Runoff Forecasting*. Up to 1 inch of plains SWE is present in Montana and the western Dakotas. Much of the plains snow in Montana and the western Dakotas fell from February 2-3. In the lower Basin, warm temperatures melted most of the plains snowpack on February 1-3; however light snowfall has recently occurred.

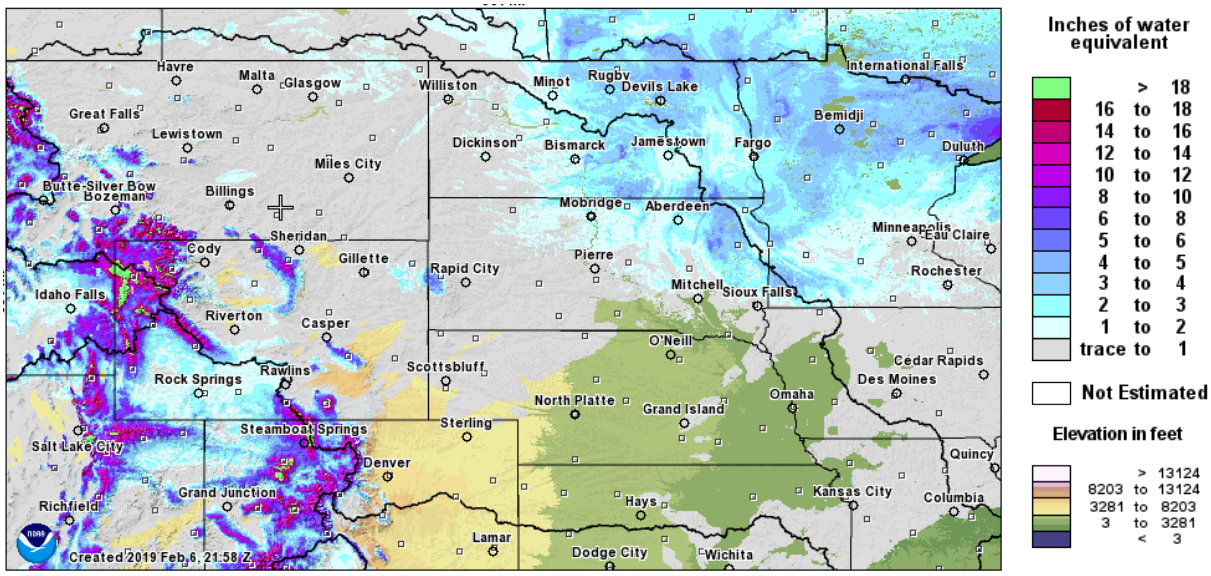


Figure 7. February 6, 2019 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reservoir reaches. It is typically NOT a factor influencing runoff at the beginning of a calendar year.

Figure 8 includes time series plots of the average mountain SWE beginning on October 1, 2018 based on the NRCS SNOTEL data for the headwater basin above Fort Peck and the incremental

basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of February 7, 2019, the Corps of Engineers computed an average mountain SWE in the Fort Peck reservoir reach of 9.8 inches, which is 90% of average based on the 1981-2010 average SWE for the Fort Peck reach. In the reservoir reach between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 8.4 inches, which is 90% of average based on the 1981-2010 average SWE for the Garrison reach. Typically by February 1, 64% of the total accumulation has occurred.

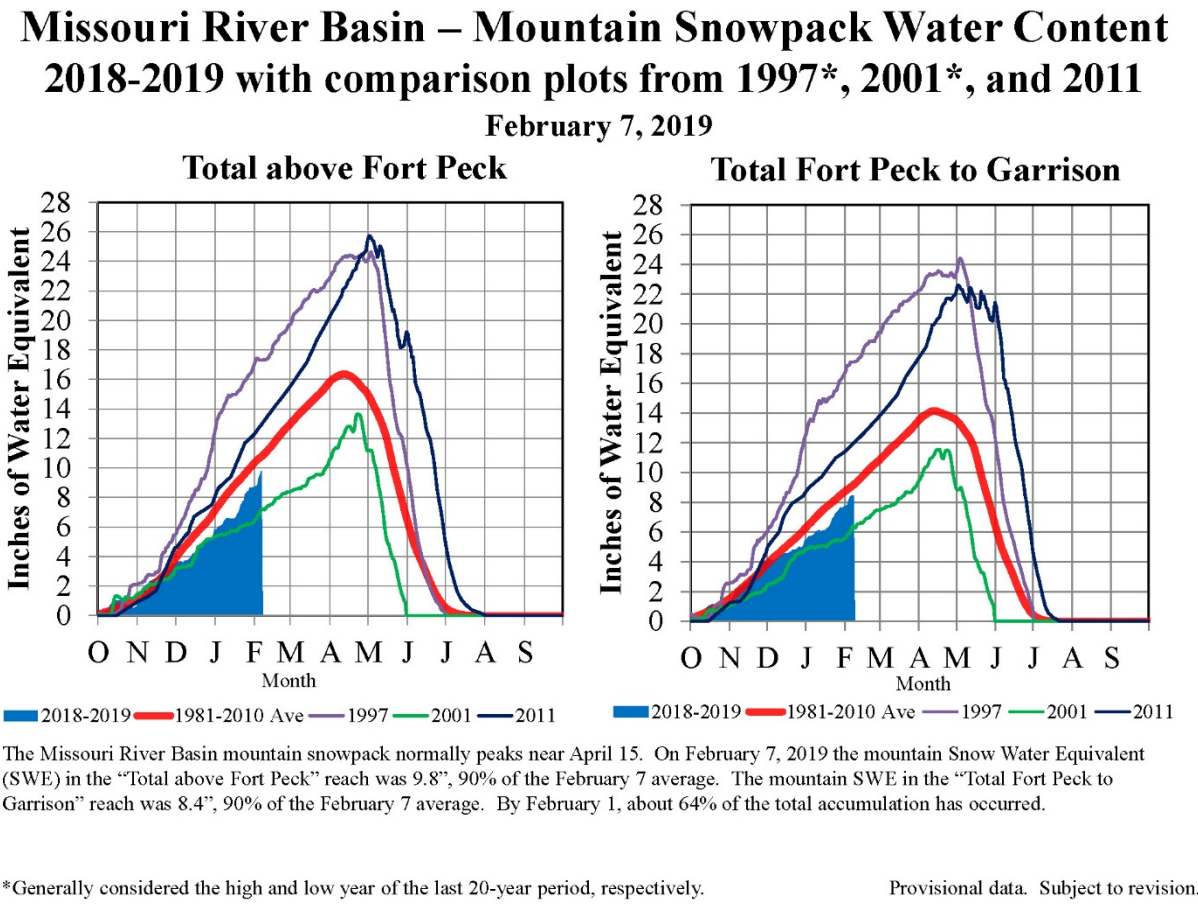


Figure 8. Mountain snowpack water content on February 7, 2019 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and

impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO Outlook indicates that ENSO-neutral conditions are present. El Niño conditions are present in the Equatorial Pacific; however, El Niño may not officially occur based on CPC criteria. During an El Niño phase of ENSO, there are increased probabilities for above-normal temperatures in the upper Missouri Basin during the winter season. ENSO-neutral conditions are likely to occur later during the calendar year.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

The CPC temperature outlook through February 17 (**Figure 9**) indicates a significant increase in chances for below-normal temperatures over the Missouri Basin, with the highest chances in the upper Basin. The precipitation outlook indicates a slight increase in the chances for above-normal precipitation over the Missouri Basin, with the greatest increase in precipitation chances over Missouri.

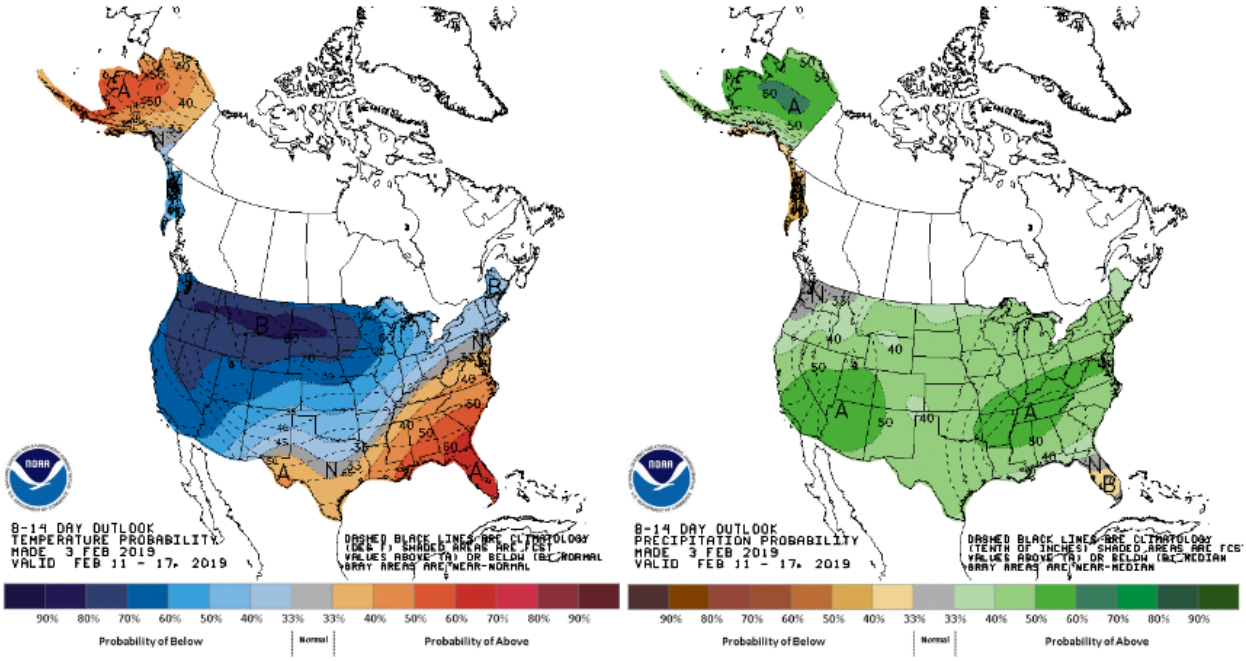


Figure 9. CPC 8-14 Day temperature and precipitation outlooks through February 17, 2019.

The February CPC outlooks in **Figure 10** indicate increased chances for below-normal temperatures in most of the Basin. With regard to precipitation, the February outlook indicates increased chances for above-normal precipitation over most of the Basin with areas of equal

chances in western Montana. The increased chance for colder-than-normal temperatures favors snow formation in the Rocky Mountains and the plains.

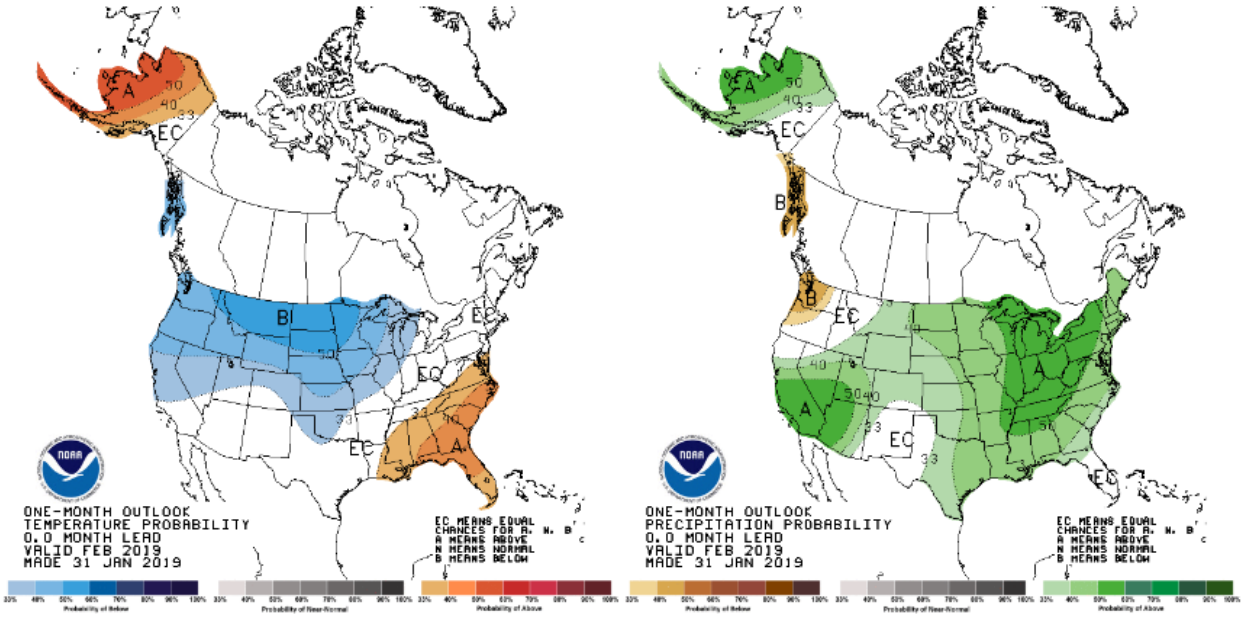


Figure 10. CPC February 2019 temperature and precipitation outlooks.

During the March-April-May 2019 period, the CPC outlooks in **Figure 11** indicate increased chances for above-normal temperatures in Montana and Wyoming, with equal chances in the remainder of the plains. With regard to the precipitation outlook, El Niño could increase chances for above-normal precipitation in the central Rockies and plains, affecting the Platte River Basin. There are equal chances for precipitation in Montana, northern Wyoming, the Dakotas and Iowa.

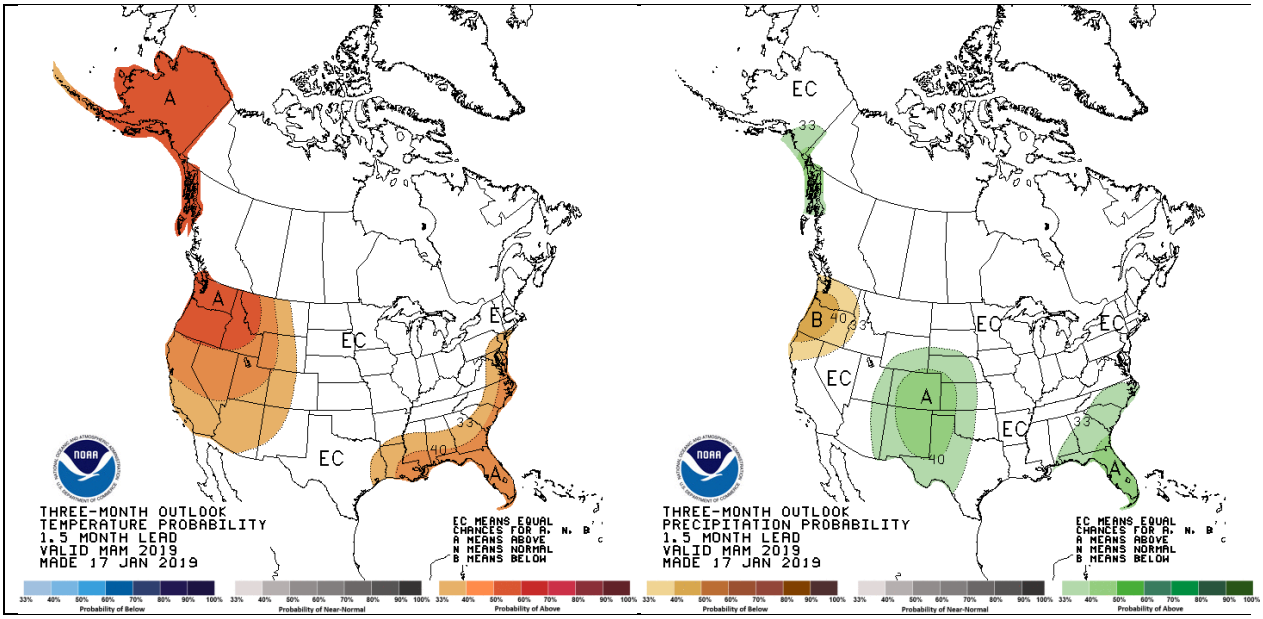


Figure 7. CPC -March-April-May 2019 temperature and precipitation outlooks.

During the June-July-August 2019 period, CPC outlooks in **Figure 12** indicate equal chances for above-normal, below-normal, and normal temperatures in much of the upper Basin. There is an increase in the chances for above-normal temperatures in western Montana and western Wyoming, Colorado and Kansas. The precipitation outlook indicates a slight increase in chances for above-normal precipitation over eastern Nebraska, eastern Kansas, Iowa and Missouri, while there is an increase in the chance for below normal precipitation in western Montana and northwestern Wyoming.

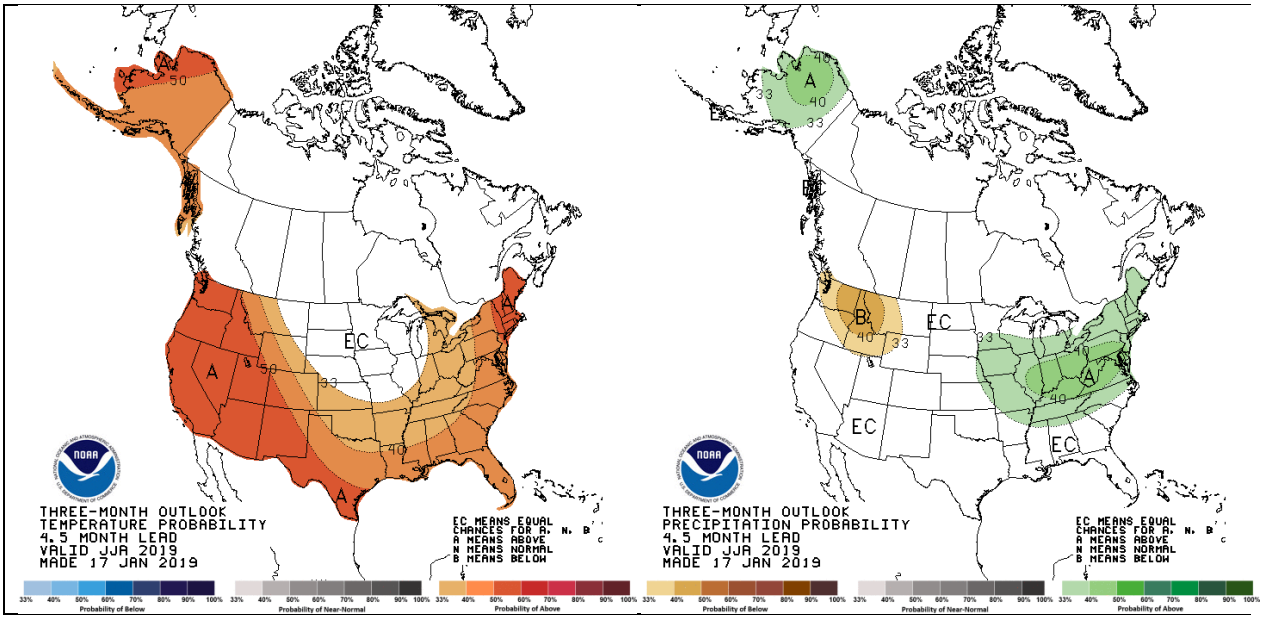


Figure 12. CPC June-July-August 2019 temperature and precipitation outlooks.

The September-October-November 2019 period outlooks in **Figure 13** indicate slight increases in the chances for above-normal temperatures, and equal chances for precipitation. During the December 2019-January-February 2020 period, CPC outlooks in **Figure 14** also indicate slight increases in the chances for above-normal temperatures, and equal chances for precipitation.

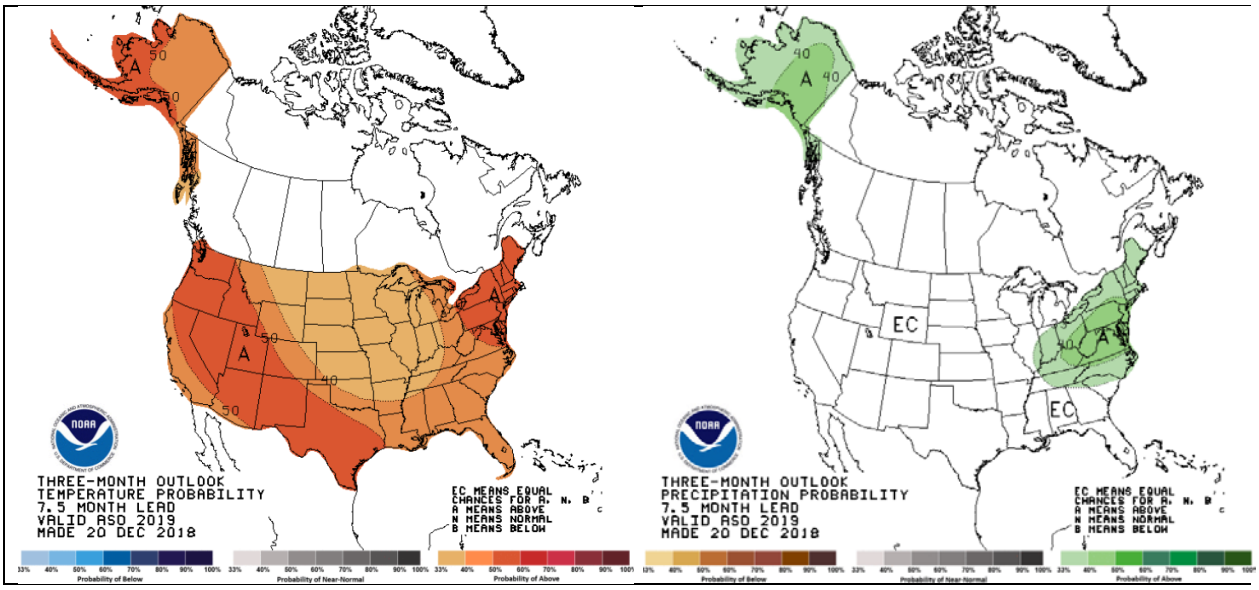


Figure 13. CPC September-October-November 2019 temperature and precipitation outlooks.

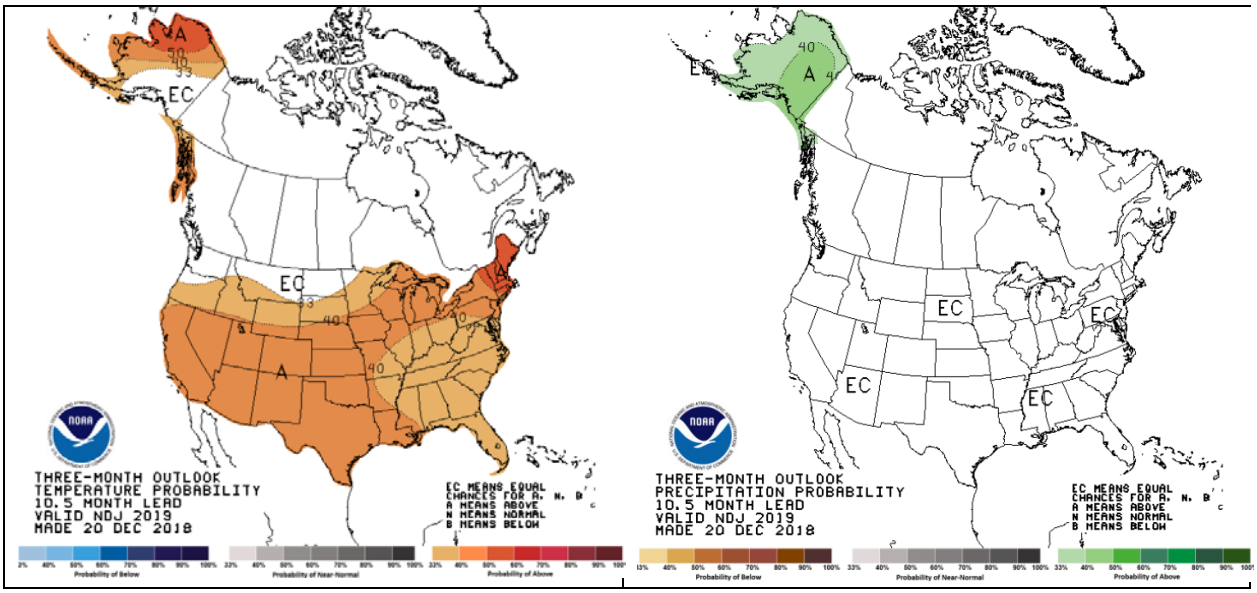


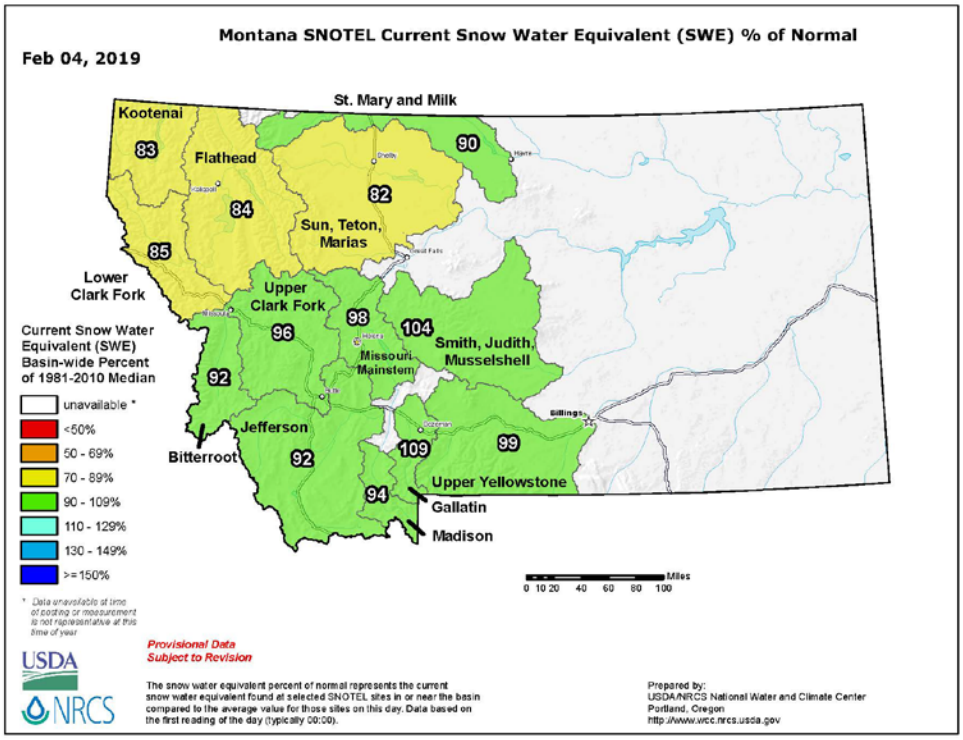
Figure 14. CPC December 2019-January-February 2020 temperature and precipitation outlooks.

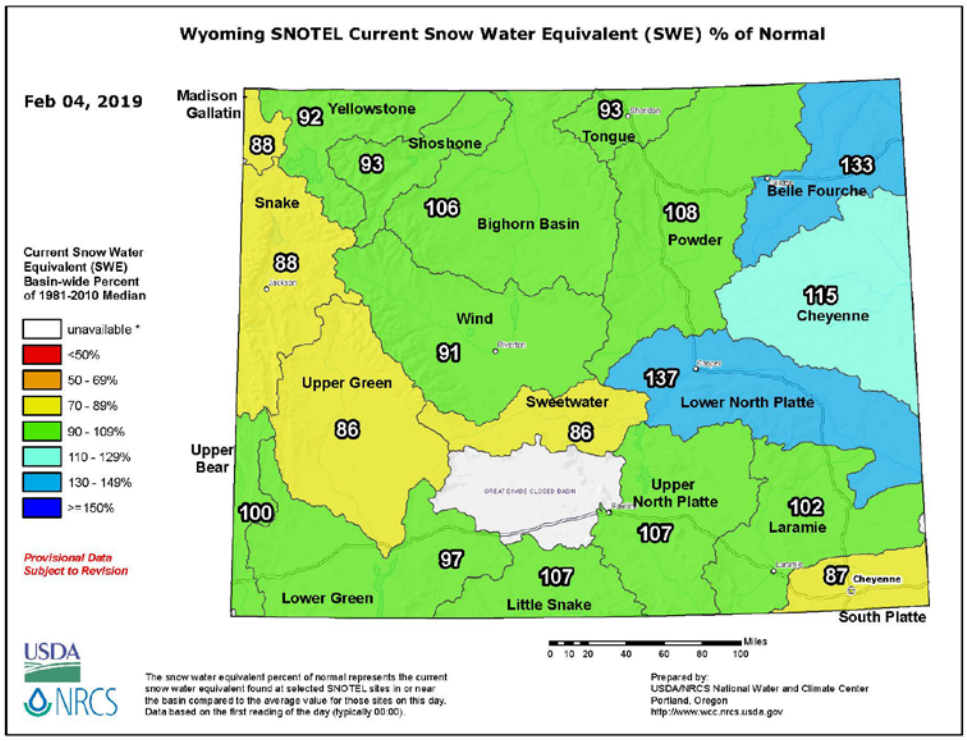
Summary

In summary, the 2019 calendar year runoff forecast is **25.6 MAF, about average**. Below-average runoff is forecast to continue in the reservoir reaches above Gavins Point Dam in February due to colder-than-normal temperatures. March and April runoff is forecast to be average to above average as spring temperatures melt the plains snowpack and river ice. Runoff in the Sioux City reach is forecast to remain above average, based on recent runoff trends, wet soil moisture conditions and the presence of *moderate* to *heavy* snowpack. May through July runoff in the Fort Peck and Garrison reaches is forecast to be below-average, due to the below-

average mountain snowpack in both reaches. Looking long-term from August to December, runoff is forecast to be about average.

Additional Figures





Water Supply Forecast
USDA NRCS National Water & Climate Center
*** - DATA CURRENT AS OF: February 05, 2019 02:59:24 PM**
- Based on February 01, 2019 forecast values

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Wind R ab Bull Lake Ck	APR-JUL	365	80	520	430	300	210	455
	APR-SEP	380	78	550	450	310	210	490
Bull Lake Ck nr Lenore (2)	APR-JUL	117	84	151	131	104	83	139
	APR-SEP	142	84	182	158	126	102	169
Boysen Reservoir Inflow (2)	APR-JUL	450	74	815	600	305	90	610
	APR-SEP	475	71	860	630	320	94	665
Greybull R at Meeteetse	APR-JUL	122	93	178	145	99	66	131
	APR-SEP	165	93	230	192	138	99	177
Shell Ck nr Shell	APR-JUL	47	85	62	53	41	32	55
	APR-SEP	55	83	72	62	48	38	66
Bighorn R at Kane (2)	APR-JUL	625	74	1130	830	420	122	840
	APR-SEP	635	70	1180	855	415	94	905
NF Shoshone R at Wapiti	APR-JUL	455	99	560	500	410	350	460
	APR-SEP	510	99	625	555	465	395	515
SF Shoshone R nr Valley	APR-JUL	197	92	255	220	174	139	215
	APR-SEP	225	92	295	255	198	158	245
Buffalo Bill Reservoir Inflow	APR-JUL	635	94	830	715	560	445	675
	APR-SEP	705	95	915	790	620	495	745
Bighorn R nr St. Xavier (2)	APR-JUL	1100	80	1730	1350	850	480	1380
	APR-SEP	1120	77	1800	1390	840	435	1460
Little Bighorn R nr Hardin	APR-JUL	80	82	137	103	57	24	98
	APR-SEP	91	82	154	116	66	29	111
Tongue R nr Dayton (2)	APR-JUL	73	85	102	85	61	44	86
	APR-SEP	84	86	115	97	72	53	98
Tongue River Reservoir Inflow (2)	APR-JUL	157	81	260	199	115	53	193
	APR-SEP	178	83	285	220	134	69	215
NF Powder R nr Hazelton	APR-JUL	7.9	87	11.2	9.2	6.6	4.6	9.1
	APR-SEP	8.5	86	11.9	9.9	7.2	5.1	9.9
Powder R at Moorhead	APR-JUL	151	85	285	205	97	17.5	177
	APR-SEP	168	86	305	220	113	32	196
Powder R nr Locate	APR-JUL	172	86	320	230	111	21	199
	APR-SEP	189	86	345	255	125	31	220
	APR-SEP	63	115	86	72	54	40	55

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
March 2019 Calendar Year Runoff Forecast
March 7, 2019

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

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

The February runoff summation for the upper Basin above Sioux City was 1.2 MAF, 102 percent of average. Runoff in the Fort Peck and Garrison reaches was 71 percent and 67 percent of average, respectively. In all other reaches, runoff was well-above average.

2019 Calendar Year Forecast Synopsis

The 2019 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA is **28.4 MAF, 112% of average.** The March forecast is an increase of 2.8 MAF since February 1. This increase is due to the increase in the accumulation of plains snowpack throughout the upper Basin, and increases in mountain snowpack. The 2019 calendar year runoff forecast above Gavins Point Dam is **24.3 MAF, 105% of average**.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 10 months, expected inflow could range from the **39.2 MAF** upper basic forecast to the **18.9 MAF** lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that ten months are being forecast for this March 1 forecast (2

month observed/10 months forecast), the range of possible wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is very large, and is attributed to all 6 reaches for the entire year. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for February 26, 2019 is shown in **Figure 1**. The drought monitor is available at http://droughtmonitor.unl.edu/. The Drought Monitor shows some areas of Abnormal Dryness (D0) present in the Bighorn Basin of Wyoming and a small area of northwestern Montana.

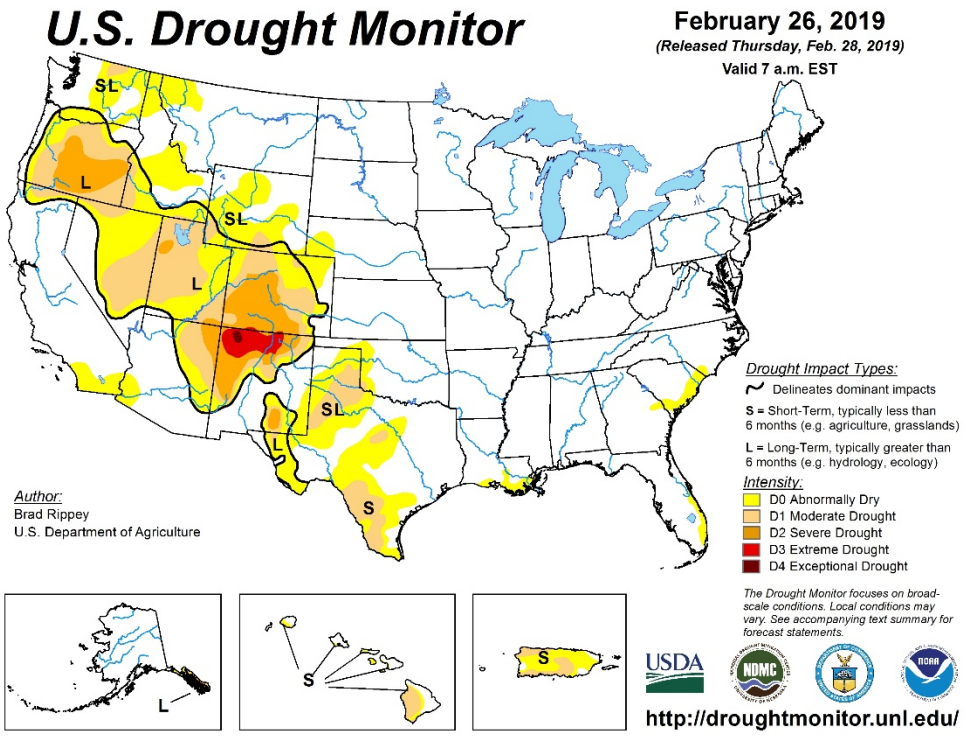


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for February 26, 2019.

The Seasonal Drought Outlook in **Figure 2**, which extends through the end of May, indicates there is likely to be no change to the few abnormally dry conditions in the Basin.

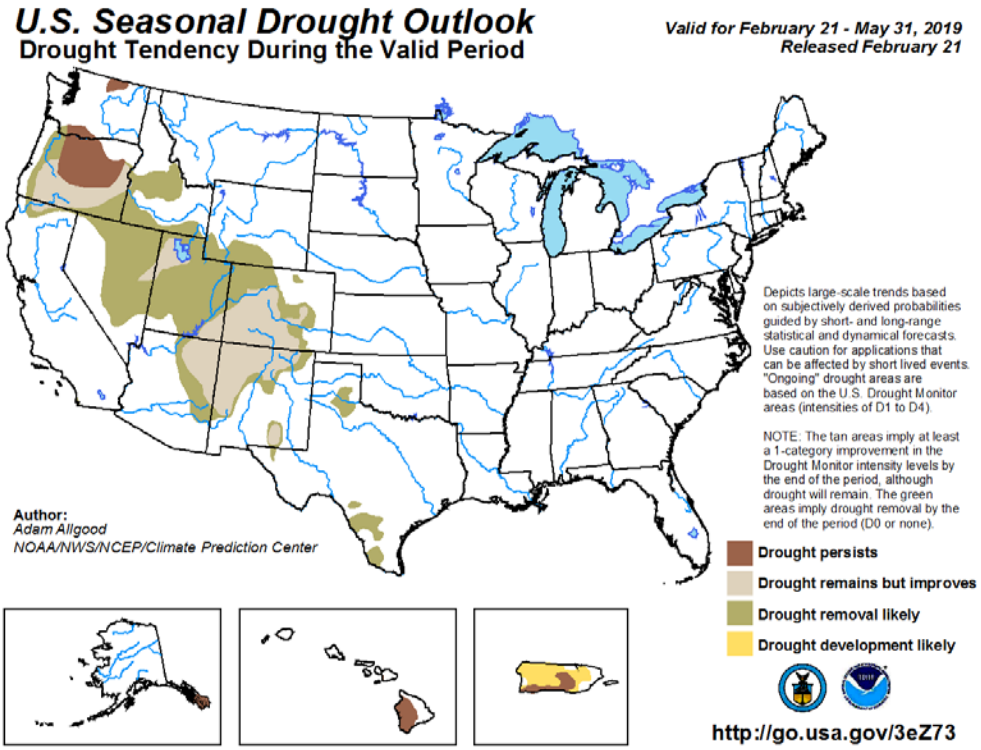


Figure 2. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. February precipitation as a percent of normal is shown in the left image of **Figure 3**, and December-January-February precipitation as a percent of normal is shown in the right image of **Figure 3**. February precipitation was well-above normal (greater than 200%) in Montana, North Dakota, northwestern Wyoming, portions of South Dakota, Iowa and eastern Nebraska. During February, moderate to heavy snowfall precipitation occurred in these above-normal precipitation areas. **Table 1** contains a list of January and February snowfall totals compared to normal snowfall totals. February snowfall was two to four times the normal amount at many locations.

December-January-February precipitation accumulations, also shown in **Figure 3**, reveal the above-normal precipitation pattern over Montana, the Dakotas, Minnesota, Nebraska, Kansas, Iowa and Missouri. December precipitation, which was above normal in eastern Montana, South Dakota, Nebraska, Iowa and Kansas, had a significant influence on this wetter-than-normal pattern. Since much of the precipitation either occurred as rainfall, or snowfall that melted, it also increased soil moisture wetness in December.

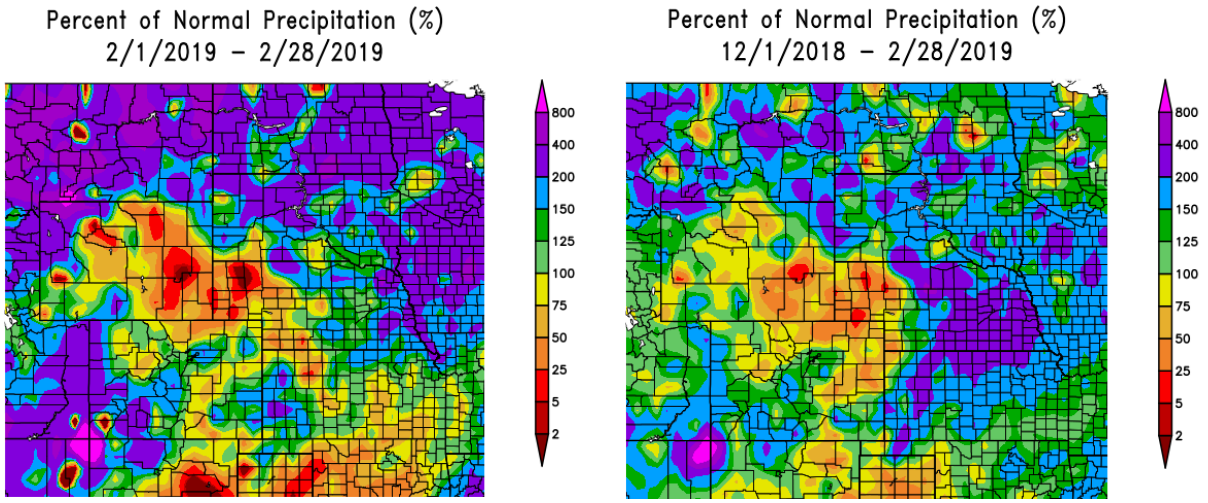


Figure 3. February 2019 and December 2018 – January-February 2019 Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 1. January and February 2019 snowfall totals compared to normal totals.

Location	January Snowfall inches	Normal Snowfall inches	February Snowfall Inches	Normal Snowfall inches
Bozeman, MT	11.8	12.9	29.2	11.1
Helena, MT	8.5	6.2	26.8	4.8
Great Falls, MT	15.1	8.6	32.3	7.9
Glasgow, MT	3.7	8.0	28.2	4.2
Livingston 12 S, MT	15.0	8.6	34.2	7.0
Billings, MT	13.7	8.4	29.4	5.9
Glendive, MT	6.9	4.1	14.1	3.4
Bismarck, ND	11.3	8.9	15.7	7.8
Jamestown St. Hos, ND	8.0	10.3	20.1	6.4
Pierre, SD	6.0	4.7	19.0	5.6
Aberdeen, SD	12.7	6.4	19.3	6.5
Watertown, SD	12.4	5.3	18.1	7.1
Brookings, SD	12.7	4.7	17.6	5.6
Sioux Falls, SD	8.1	7.7	21.0	6.6
Worthington, MN	18.0	7.0	35.9	5.9
Sioux City, IA	1.7	6.7	18.6	6.4
Omaha, NE	12.9	6.1	27.0	5.9
Lincoln, NE	9.7	6.4	23.2	5.4
Nebraska City, NE	20.0	6.5	19.0	7.1
Maryville, MO	13.5	3.2	15.1	4.6
Kansas City, MO	9.3	4.6	8.7	5.3

Temperature

February temperature departures, shown in degrees Fahrenheit (deg F) in the left image of **Figure 4**, were much colder than normal**.** In most of the upper Basin, departures ranged from 15 to more than 25 degrees BELOW normal. These cold temperatures directly influenced the rapid formation of mountain and plains snowpack, as well as very deep soil frost depths. Temperatures were also below normal in the lower Basin, ranging from 10 to 15 deg F below normal in southeastern South Dakota, western Iowa, and Nebraska, to just below normal in Missouri. Overall December-January-February temperature departures, shown in the right image of **Figure 4**, have been below normal as a result of very cold February temperatures. Three-month departures ranged from 2 to more than 6 deg F BELOW normal in the upper Basin, and near normal to slightly below normal in the lower Basin.

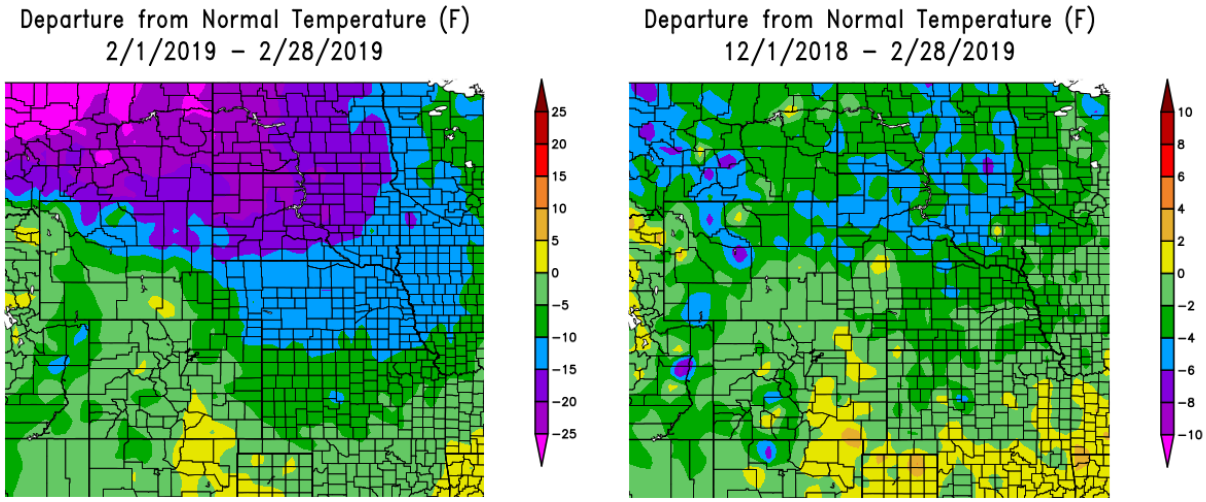


Figure 4. February 2019 and December 2018 – January-February 2019 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Frost Conditions

Soil frost in an important runoff factor as snow begins to melt. Frost depth is the depth of frozen ground from the soil surface. Soil frost acts as a barrier to snowmelt and rainfall infiltration into the soil. The deeper the depth of frost formation, the greater the barrier for water infiltration, and thus the higher the runoff potential. The depth of frost penetration or frost depth is shown in **Figure 5**. The NWS monitors frost depth at each of their NWS warning forecast office locations. The number under the station location denotes the number of inches of frost formation, while an "M" denotes a missing value. The **Figure 5** map shows that frozen ground has developed relatively deep in the upper Basin, and it is frozen at nearly all locations in the Missouri River Basin, including the southernmost point of Springfield, MO (SPFM7). The deepest frost depth is 50 inches at Bismarck, ND (BRKN8). The depth at Sioux Falls (FSDS2) is 23 inches, not the 0-inch depth shown in the map. Due to the extensive and deep formation of frost in the Missouri Basin, spring 2019 runoff potential is higher than normal.

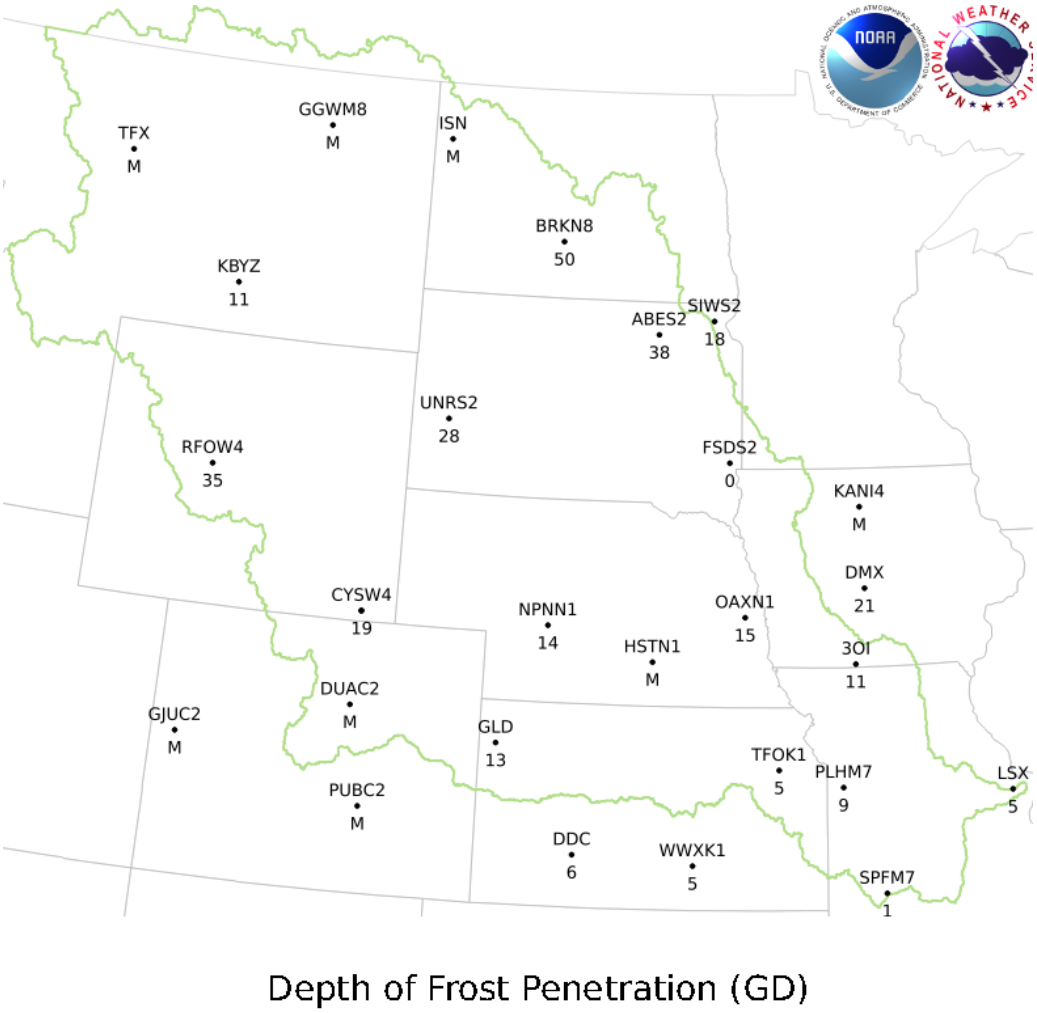


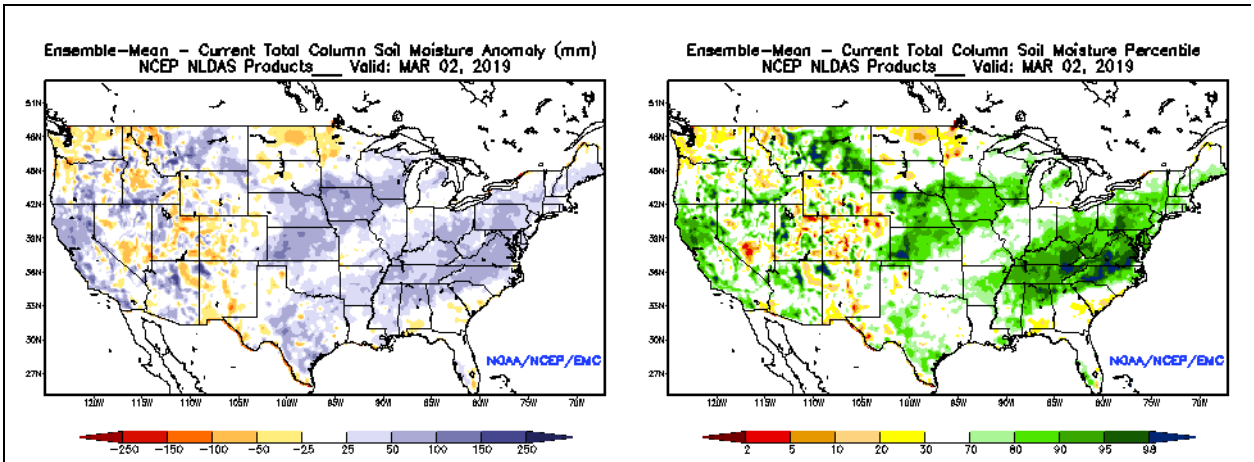
Figure 5. NWS frost depth (inches) as of March 7, 2019.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the soil moisture conditions will provide some insight into late winter and early spring runoff potential.

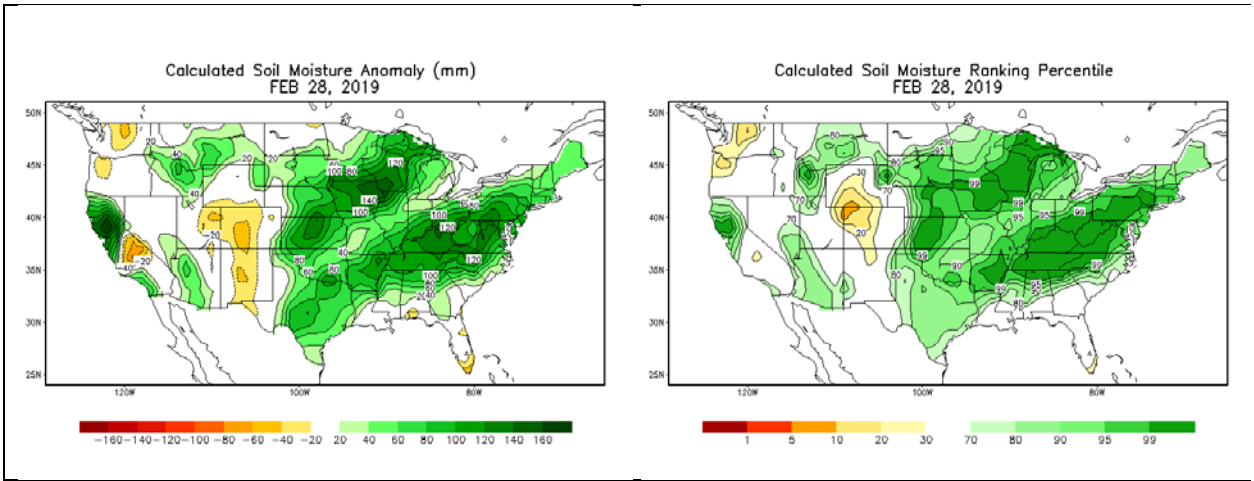
Figure 6 shows the March 2, 2019 NOAA NLDAS ensemble soil moisture anomaly and soil moisture percentile. **Figure 7** shows the February 28, 2019 NOAA CPC soil moisture anomaly and soil moisture percentile. Soil moisture conditions in both soil moisture maps show similar conditions. Soil moisture anomalies and percentiles are well-above normal in Montana, northeastern Wyoming, southern South Dakota, Nebraska, Iowa and Kansas. Soil moisture conditions are particularly wet in Nebraska, Iowa and Kansas, where percentiles are greater than

the 90th percentile for wetness over much of the three states. Conditions are normal to slightly below normal over the rest of the Dakotas, Wyoming and Colorado. Spring runoff could potentially be above normal under normal winter precipitation and snowfall accumulations due to the above-normal soil moisture conditions.



Soil Moisture Anomaly (mm)	Soil Moisture Percentile

Figure 6. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/



Soil Moisture Anomaly (mm)	Soil Moisture Percentile

Figure 7. NOAA CPC Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA CPC. https://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml

Plains Snowpack

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. A common misperception is that the March-April runoff is a result of plains snowmelt only. Historically, about 25% of annual runoff occurs in March and April, during the time when plains snow is melting, due to both melting snowpack and rainfall runoff. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more than a week in advance. Thus, the March-April runoff forecast is formulated based on existing

plains snowpack and existing basin conditions and hydrologic forecasts, which for this year primarily includes long-term precipitation outlooks. At this time of year, plains snowpack is a good indicator for March-April runoff; however, as the snowpack reaches its ultimate peak accumulation, better forecasts of future runoff can be made.

Plains snowpack has increased significantly in coverage over the upper Basin during the past 30 days. The National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC), modeled snow assessment from February 7 is shown in **Figure 8**, and the NOHRSC modeled snow assessment from March 7 is shown in **Figure 9**. The heaviest plains snowpack is in eastern South Dakota in the James and Big Sioux River basins, unregulated basins that drain into the Missouri River below Gavins Point Dam. The NWS's National Operational Hydrologic Remote Sensing Center (NOHRSC) modeled snow assessment indicates a moderate-to-heavy snowpack in these basins. Plains SWE ranges from 4 to 6 inches of SWE in the Big Sioux River basin, and possibly 2 to 4 inches of SWE in the central Dakotas including the James River basin. The NOHRSC snow map is even showing isolated areas of 6 to 8 inches of SWE in some portions of the Big Sioux River basin. Farther west, light-to-moderate SWE, ranging from 1 to 3 inches, has developed in the western Dakotas. In western and central Montana, heavy snowfall accumulated in February, forming 2 to 3 inches of SWE.

Plains SWE – February 7, 2019

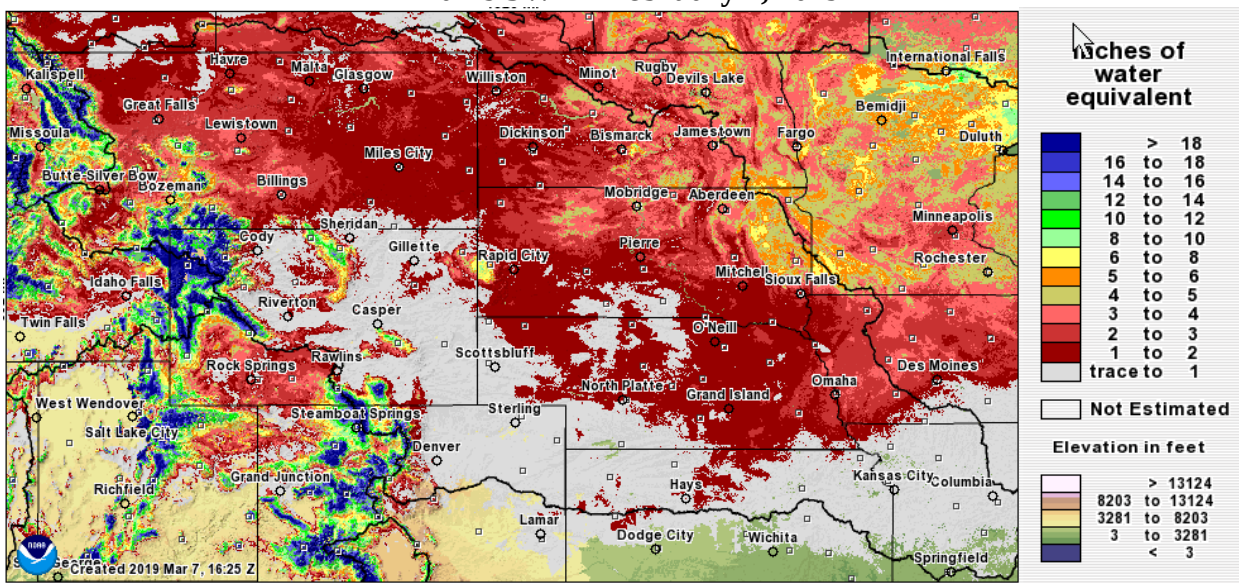


Figure 8. February 7, 2019 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Plains SWE – March 7, 2019

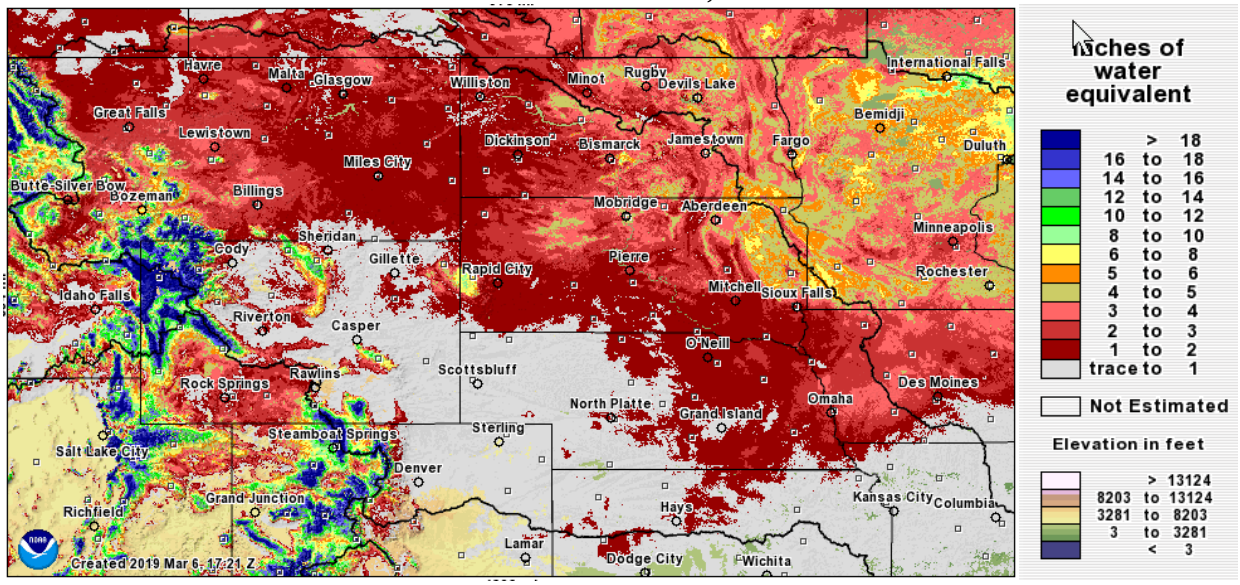


Figure 9. March 7, 2019 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

MRBWM obtains measurements of plains snow depth and SWE every two weeks while plains snowpack persists in the upper Missouri Basin. The most recent measurements were taken during the week of March 4, and are posted to the MRBWM website at: http://www.nwd-mr.usace.army.mil/rcc/snowsurvey/snowsurvey.html. As of early March, the heaviest measured SWE values range from 3 to 4 inches in northeastern South Dakota. Generally, SWE amounts range from 1.5 to 2.5 inches at the locations measured in the Dakotas and northeastern Montana.

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reservoir reaches. It is typically NOT a factor influencing runoff at the beginning of a calendar year.

Figure 10 includes time series plots of the average mountain SWE beginning on October 1, 2018 based on the NRCS SNOTEL data for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of March 7, the Corps of Engineers computed an average mountain SWE in the Fort Peck reservoir reach of 14.5 inches, which is 107% of average based on the 1981-2010 average SWE for the Fort Peck reach. In the reservoir reach between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 11.9 inches, which is 103% of average based on the 1981-2010 average SWE for the Garrison reach. Typically by March 1, 79% of the total accumulation has occurred. On February 7, 2019 average mountain SWE in the Fort Peck reservoir reach and Fort Peck to Garrison reservoir reach were both 90% of average.

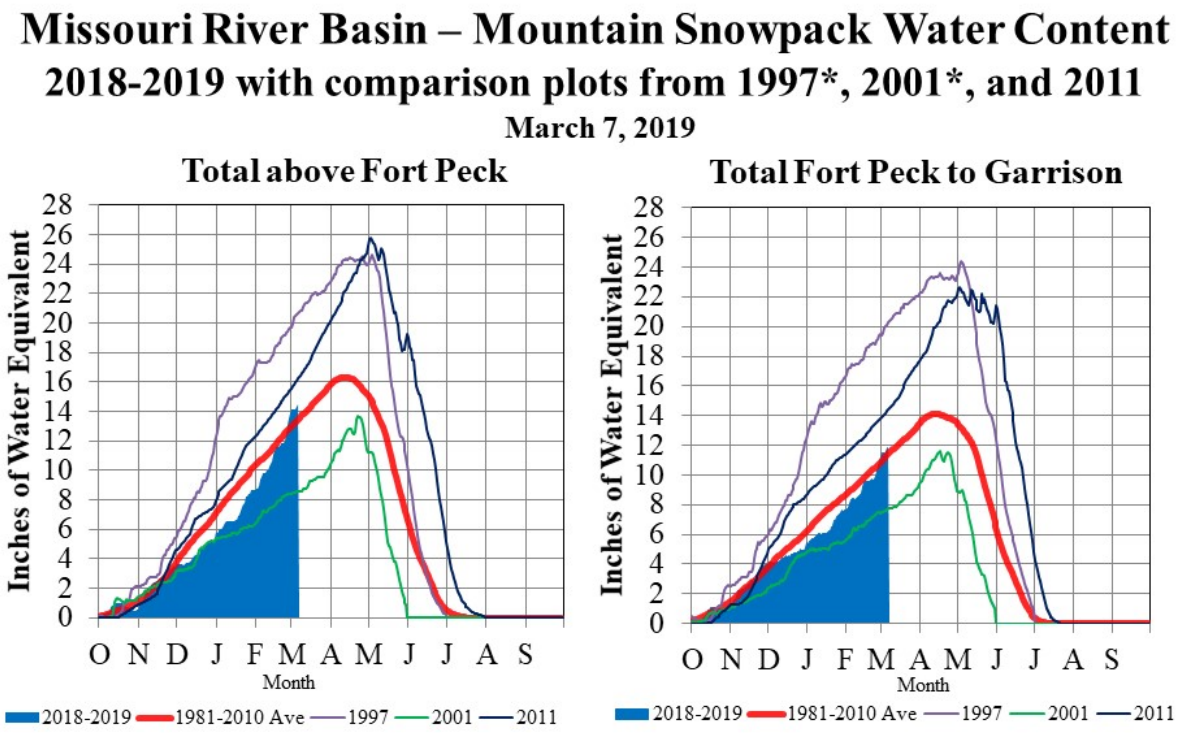


Figure 10. Mountain snowpack water content on March 7, 2019 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO Outlook indicates that ENSO-neutral conditions are present. Weak El Niño conditions are present in the Equatorial Pacific, and there is a 55 percent chance it will continue through the Northern Hemisphere spring 2019. During an El Niño phase of ENSO, there are increased probabilities for above-normal temperatures in the upper Missouri Basin during the winter season. ENSO-neutral conditions are likely to occur later during the calendar year.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

With regard to future weather, the NWS is forecasting additional winter precipitation over southern Montana, Wyoming, South Dakota and the lower Basin for March 8-15. This includes two winter storms that are forecast to move northeastward from the lower Basin into the Midwest, bringing significant rain and snow to Kansas, Missouri, eastern Nebraska, Iowa, eastern South Dakota and Minnesota.

Following this period of precipitation, the CPC temperature outlook for March 15-21 (**Figure 11**) indicates a significant increase in chances for below-normal temperatures over the Missouri Basin, with the highest chances in the lower Basin. The precipitation outlook indicates an increase in the chances for below-normal precipitation over the Missouri Basin.

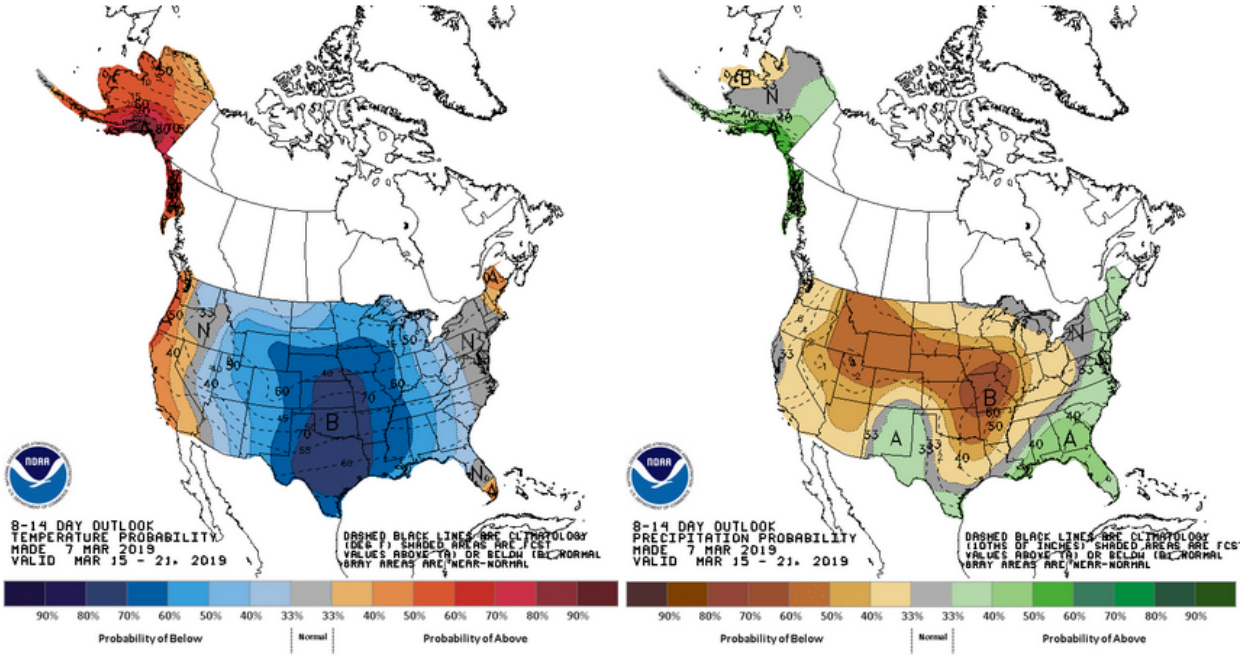


Figure 11. CPC 8-14 Day temperature and precipitation outlooks through March 21, 2019.

The March CPC outlooks in **Figure 12** indicate increased chances for below-normal temperatures in most of the Basin. With regard to precipitation, the March outlook indicates increased chances for above-normal precipitation over most of the Basin with areas of equal chances in western Montana. The increased chance for colder-than-normal temperatures favors snow formation in the Rocky Mountains and the plains.

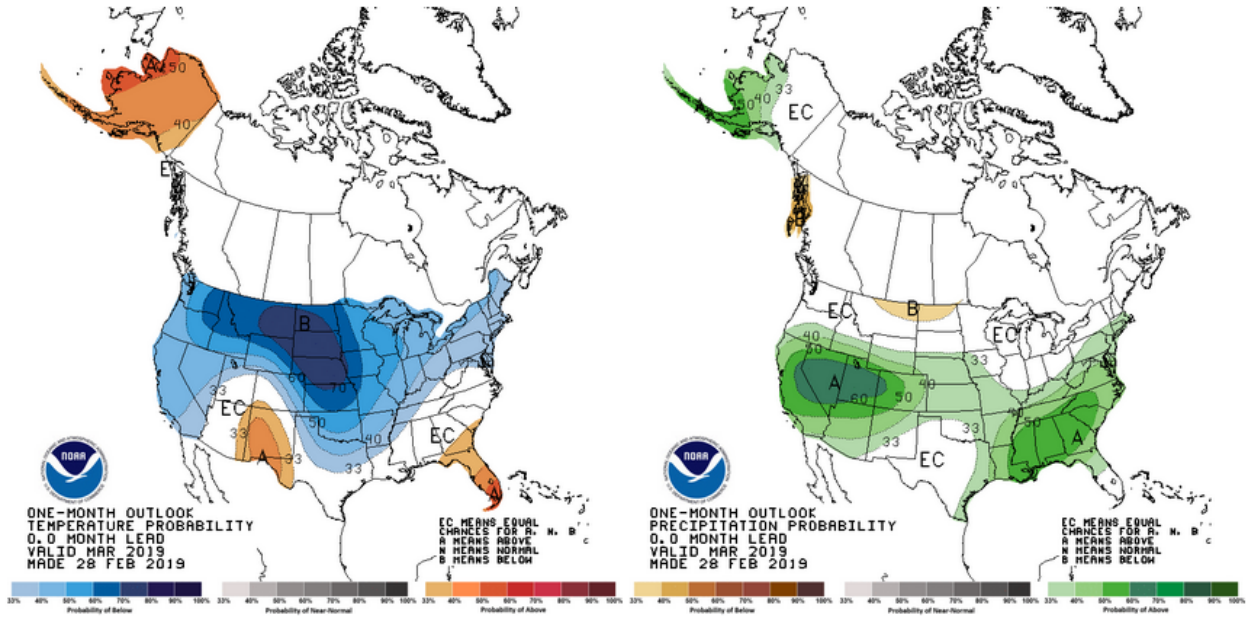


Figure 12. CPC March 2019 temperature and precipitation outlooks.

During the April-May-June 2019 period, the CPC outlooks in **Figure 13** indicate increased chances for above-normal temperatures in western Montana and Wyoming, with equal chances in the remainder of the Missouri Basin. With regard to the precipitation outlook, there are increased chances for precipitation in the lower Basin, South Dakota and part of Wyoming. There are equal chances for precipitation in Montana and North Dakota.

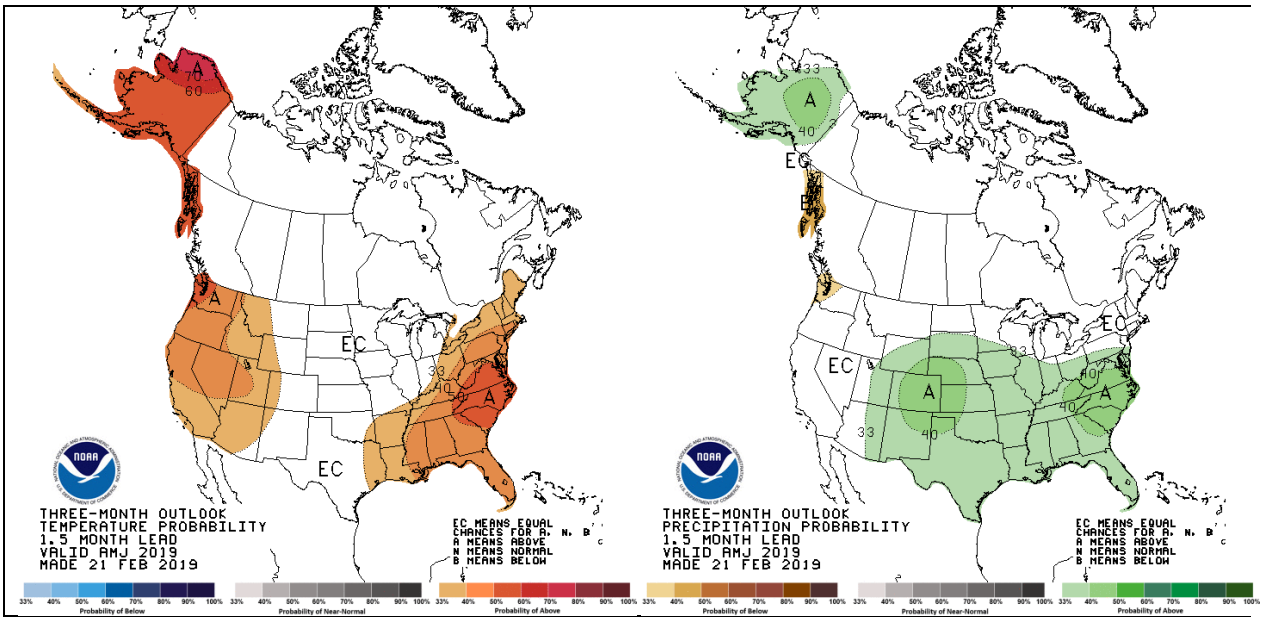


Figure 13. CPC April-May-June 2019 temperature and precipitation outlooks.

During the July-August-September 2019 period, CPC outlooks in **Figure 14** indicate equal chances for above-normal, below-normal, and normal temperatures in eastern Montana, the Dakotas, much of Nebraska and Iowa. In all other areas including much of Montana and

Wyoming, there is an increased chance for above-normal temperatures. The precipitation outlook indicates a slight increase in chances for above-normal precipitation over eastern Nebraska, eastern Kansas, Iowa and Missouri, while there is an increase in the chance for below-normal precipitation in western Montana and western Wyoming.

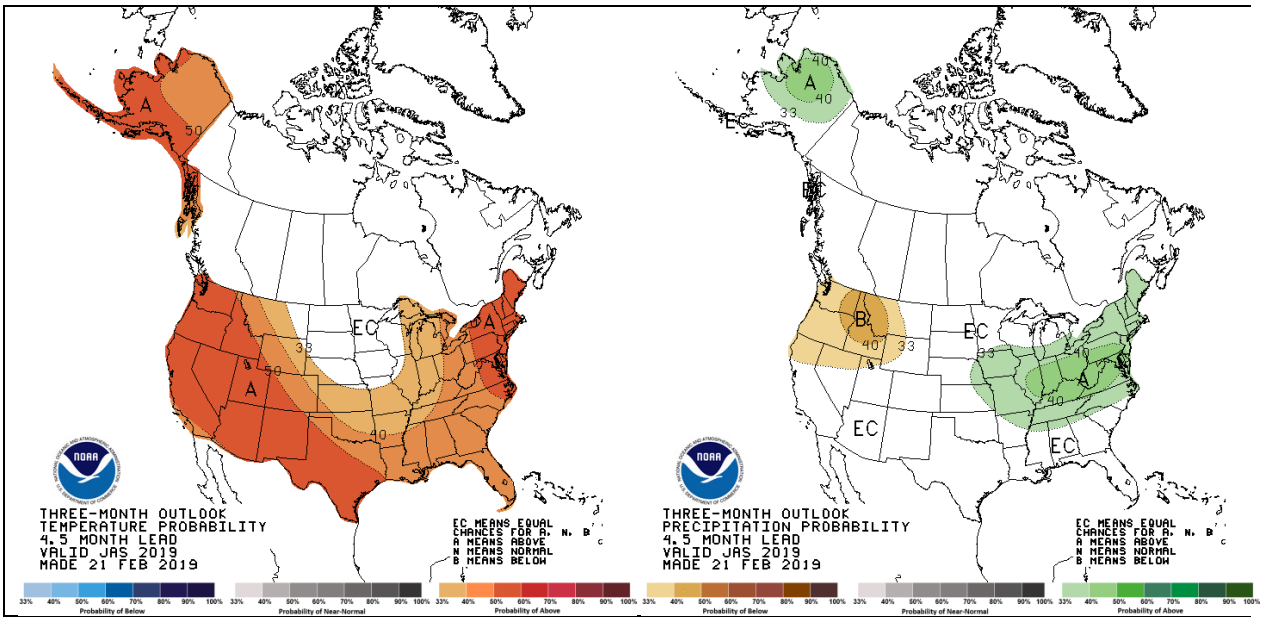


Figure 14. CPC July-August-September 2019 temperature and precipitation outlooks.

The October-November-December 2019 outlooks in **Figure 15** indicate an increase in the chances for above-normal temperatures in much of the Missouri Basin with the exception of equal chances in northern Montana and North Dakota. In regard to precipitation, there are equal chances throughout the Missouri Basin.

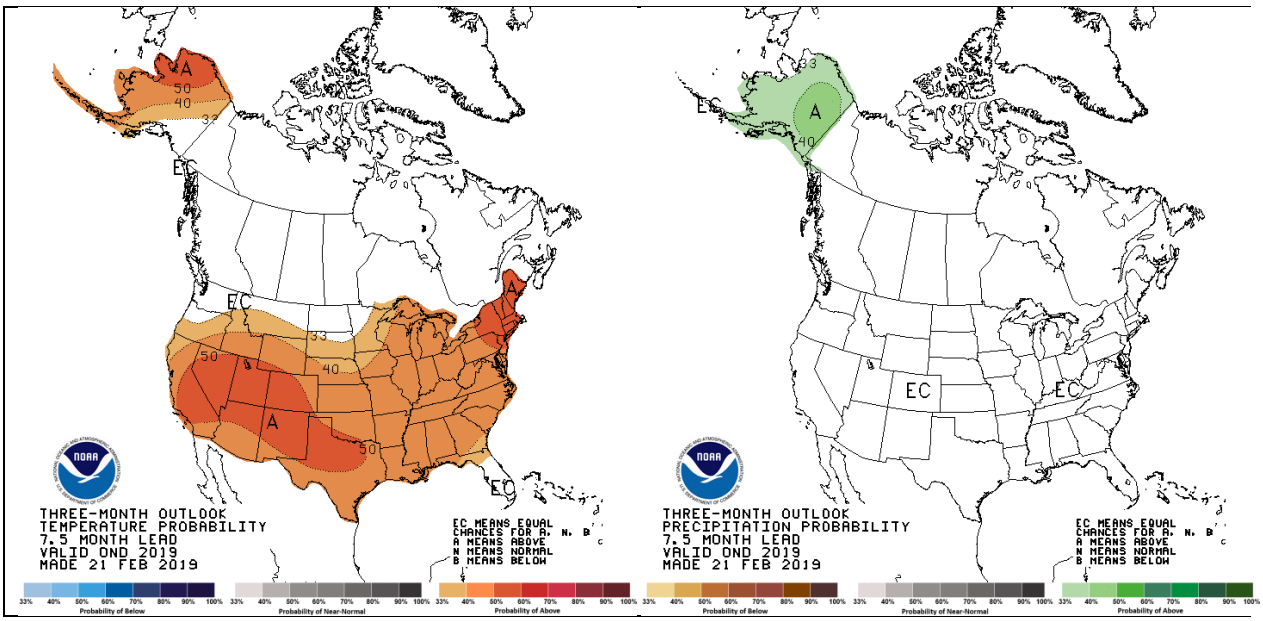
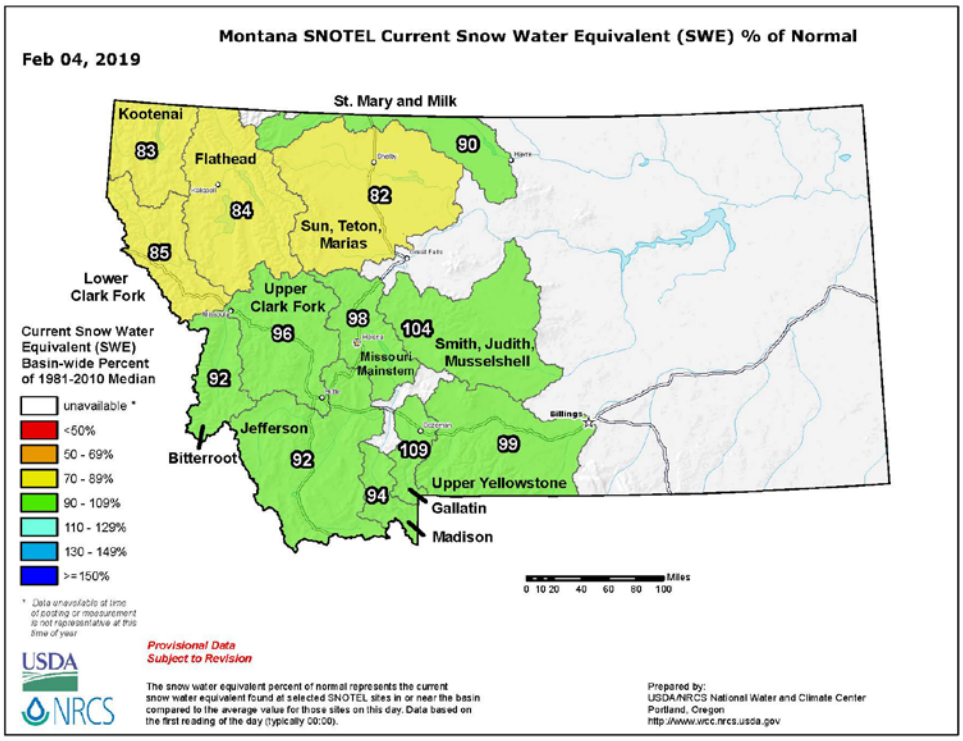


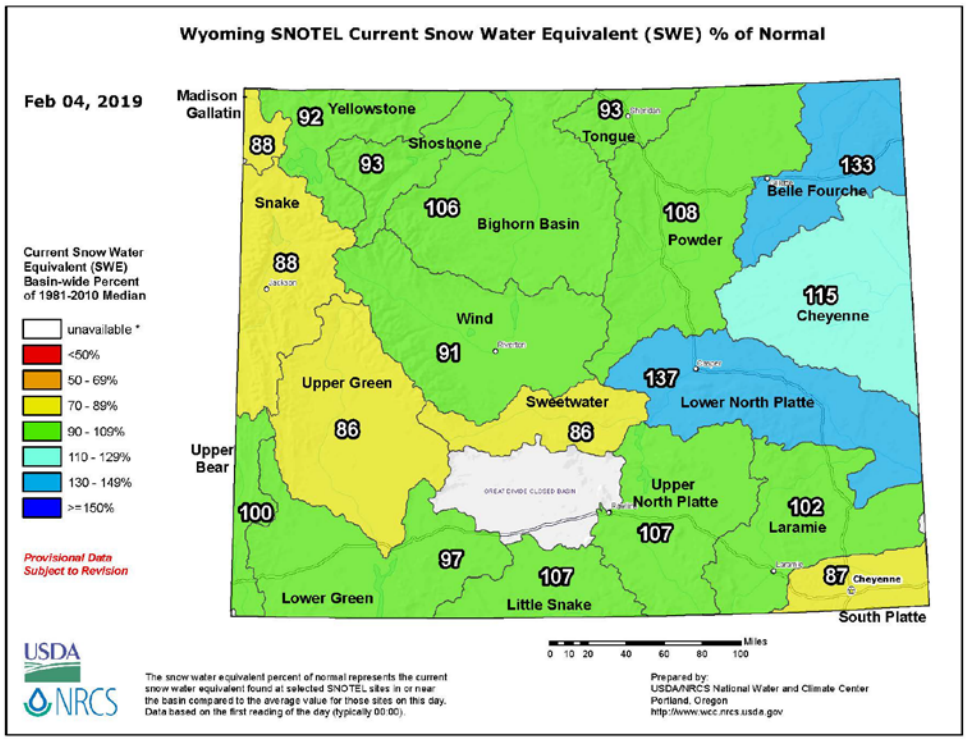
Figure 15. CPC October-November-December 2019 temperature and precipitation outlooks.

Summary

In summary, the 2019 calendar year runoff forecast is **28.4 MAF, 112% of average**. The March forecast is an increase of 2.8 MAF since February 1. This increase is due to the increase in the accumulation of plains snowpack throughout the upper Basin, and increases in mountain snowpack. The 2019 calendar year runoff forecast above Gavins Point Dam is **24.3 MAF, 105% of average**.

Additional Figures





USDA NRCS National Water & Climate Center
*** - DATA CURRENT AS OF: March 06, 2019 12:30:57 PM**
- Based on March 01, 2019 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow (2)	APR-JUL	90	93	111	98	82	69	97
	APR-SEP	104	93	127	113	95	81	112
St. Mary R at Intl Boundary (2)	APR-JUL	395	91	510	440	350	285	435
	APR-SEP	460	91	585	510	410	335	505
Lima Reservoir Inflow (2)	APR-JUL	99	132	133	113	85	65	75
	APR-SEP	108	135	146	123	93	70	80
Clark Canyon Reservoir Inflow (2)	APR-JUL	97	96	154	120	74	40	101
	APR-SEP	118	98	185	145	91	51	120
Jefferson R nr Three Forks (2)	APR-JUL	820	111	1200	975	670	445	740
	APR-SEP	880	110	1300	1050	710	460	800
Hebgen Lake Inflow (2)	APR-JUL	415	112	495	450	385	340	370
	APR-SEP	525	112	615	560	490	435	470
Ennis Lake Inflow (2)	APR-JUL	715	114	860	775	655	565	625
	APR-SEP	880	114	1050	950	810	705	775
Missouri R at Toston (2)	APR-JUL	2050	115	2680	2310	1790	1410	1790
	APR-SEP	2350	114	3090	2650	2050	1610	2070
Smith R bl Eagle Ck (2)	APR-JUL	119	112	175	142	96	63	106
	APR-SEP	130	112	196	157	103	64	116
Gibson Reservoir Inflow (2)	APR-JUL	345	87	445	385	305	245	395
	APR-SEP	385	88	490	425	340	275	440
Marias R nr Shelby (2)	APR-JUL	300	83	455	360	240	147	360
	APR-SEP	315	84	475	380	250	153	375

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	APR-JUL	62	105	72	66	58	52	59
	APR-SEP	78	105	90	83	73	66	74
Wind R ab Bull Lake Ck	APR-JUL	470	103	610	525	410	325	455
	APR-SEP	500	102	660	565	435	340	490
Bull Lake Ck nr Lenore (2)	APR-JUL	134	96	168	148	120	100	139
	APR-SEP	161	95	205	178	144	119	169
Boysen Reservoir Inflow (2)	APR-JUL	610	100	975	760	465	245	610
	APR-SEP	655	98	1040	815	500	265	665
Greybull R at Meeteetse	APR-JUL	129	98	190	154	105	69	131
	APR-SEP	175	99	245	205	145	103	177
Shell Ck nr Shell	APR-JUL	49	89	65	55	43	33	55
	APR-SEP	60	91	77	67	53	43	66
Bighorn R at Kane (2)	APR-JUL	815	97	1360	1040	595	275	840
	APR-SEP	870	96	1450	1110	630	280	905
NF Shoshone R at Wapiti	APR-JUL	550	120	655	590	510	445	460
	APR-SEP	610	118	730	660	565	495	515
SF Shoshone R nr Valley	APR-JUL	235	109	290	260	215	183	215
	APR-SEP	270	110	335	300	245	210	245
Buffalo Bill Reservoir Inflow	APR-JUL	785	116	980	865	710	595	675
	APR-SEP	865	116	1070	950	780	655	745
Bighorn R nr St. Xavier (2)	APR-JUL	1450	105	2120	1720	1170	770	1380
	APR-SEP	1520	104	2270	1830	1220	775	1460
Little Bighorn R nr Hardin	APR-JUL	77	79	135	100	54	19.4	98
	APR-SEP	87	78	151	113	61	23	111
Tongue R nr Dayton (2)	APR-JUL	67	78	98	80	55	36	86
	APR-SEP	78	80	111	91	64	44	98
Tongue River Reservoir Inflow (2)	APR-JUL	142	74	250	185	97	32	193
	APR-SEP	160	74	275	205	113	45	215
NF Powder R nr Hazelton	APR-JUL	8.3	91	12.2	9.9	6.7	4.4	9.1
	APR-SEP	8.9	90	13.0	10.6	7.3	4.9	9.9
Powder R at Moorhead	APR-JUL	153	86	300	210	94	7.6	177
	APR-SEP	169	86	320	230	109	20	196
Powder R nr Locate	APR-JUL	174	87	335	240	109	14.3	199

APR-SEP	190	86	360	260	122	22	220

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
April 2019 Calendar Year Runoff Forecast
April 2, 2019

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

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

Observed March runoff in the upper Basin above Sioux City was nearly 11 MAF, which set a new record for March and is nearly 4 times the average March runoff. It was the record highest March runoff for Fort Randall, and more runoff than that reach normally sees in a year. It was almost twice the record highest March runoff for Gavins Point, which previously occurred in 1952. It was the record highest March runoff for Sioux City, and more runoff than that reach typically sees in a year. It was the 7th highest March runoff for Fort Peck, 2nd highest for Garrison, and 2nd highest for Oahe.

2019 Calendar Year Forecast Synopsis

The 2019 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA is **38.2 MAF, 151% of average.** The April forecast is an increase of 9.8 MAF since March 1. About 8 MAF of the nearly 10 MAF increase in the forecast between March 1 and April 1 is from observed March runoff alone. The record runoff in March was caused by heavy plains snowpack and additional snowfall melting on frozen soils that were already saturated. This coincided with

2-4 inches of rainfall over Nebraska, Iowa, and South Dakota. The 2019 calendar year runoff forecast above Gavins Point Dam is **31.7 MAF, 138% of average**.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 9 months, expected inflow could range from the **48.8 MAF** upper basic forecast to the **29.0 MAF** lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that nine months are being forecast for this April 1 forecast (3 months observed/9 months forecast), the range of possible wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is very large, and is attributed to all 6 reaches for the entire year. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for March 26, 2019 is shown in **Figure 1**. The drought monitor is available at http://droughtmonitor.unl.edu/. The Drought Monitor shows some areas of Abnormal Dryness (D0) present in the Bighorn Basin of Wyoming and a small area of northwestern Montana.

The Seasonal Drought Outlook in **Figure 2**, which extends through the end of June, indicates there is likely to be no change to the few abnormally dry conditions in the Basin.

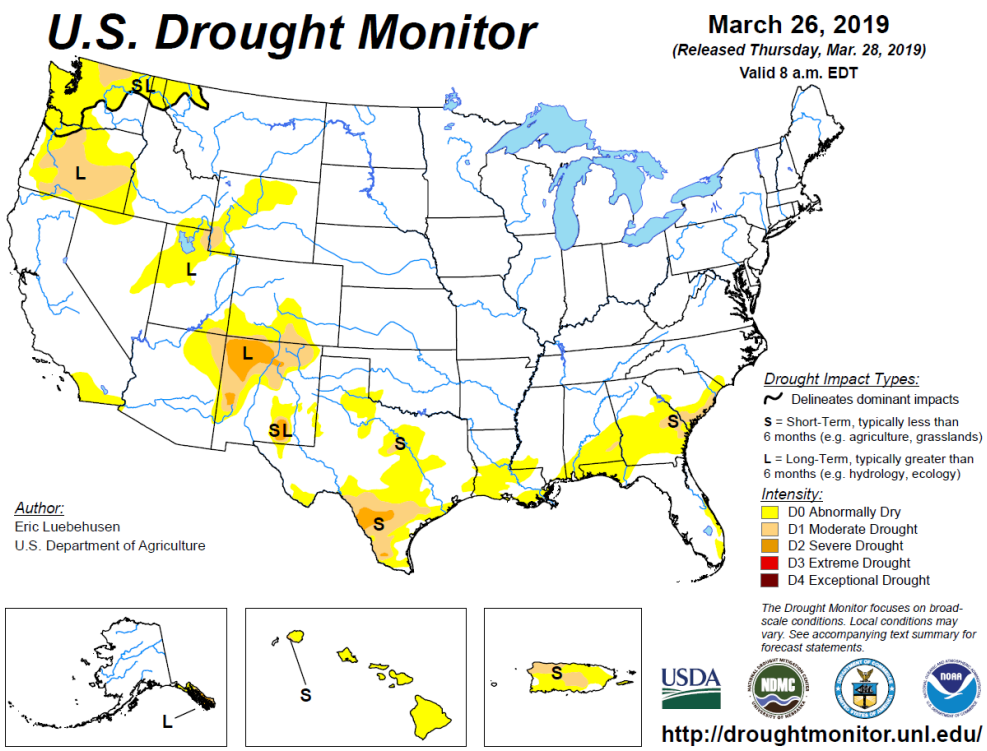


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for March 26, 2019.

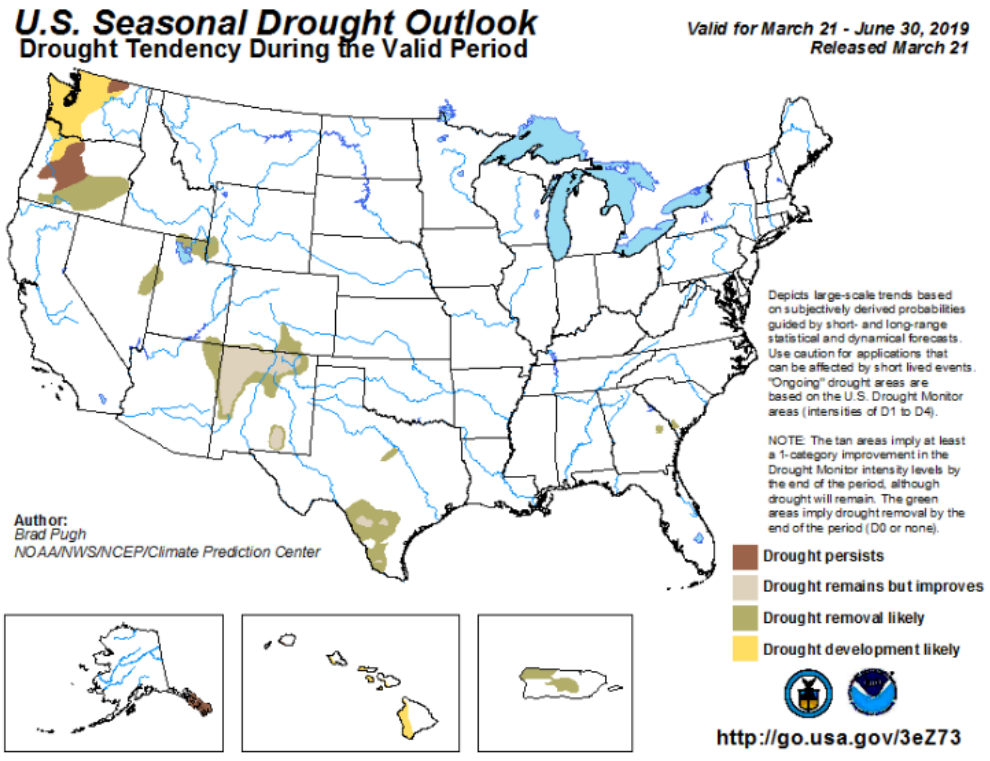


Figure 2. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Beginning on March 7, some light precipitation in the form of snow added several inches of snow depth to the central plains with additional SWE amounts of 0.1 to 0.3 inches. Two days later on March 9, light rain showers accompanied by above-freezing temperatures brought light to moderate precipitation to Nebraska, western Iowa and southeastern South Dakota. Rainfall ranged from 0.5 to 1.0 inches in eastern South Dakota and 0.25 to 0.5 inches in eastern Nebraska. Some of this water was stored in the existing snowpack, while some of it infiltrated to the soil surface, and caused some additional snowmelt. By March 11, daytime high temperatures were above freezing as a deep low pressure system, referred to as the "Bomb Cyclone" for its rapid development and unusually low surface pressure, developed to the east of the Rocky Mountains and moved into the central plains. Over the course of two days from March 13 to 14, it produced moderate rainfall over Nebraska, South Dakota and Iowa, as well as very heavy snow in western Nebraska and southwestern South Dakota, and light snow in northern Nebraska and southeastern South Dakota. Due to the above-freezing temperatures and moderate rainfall, the plains snowpack rapidly melted in central and eastern Nebraska, western Iowa and southeastern South Dakota. **Figure 11** shows the modeled snowmelt from March 13-15.

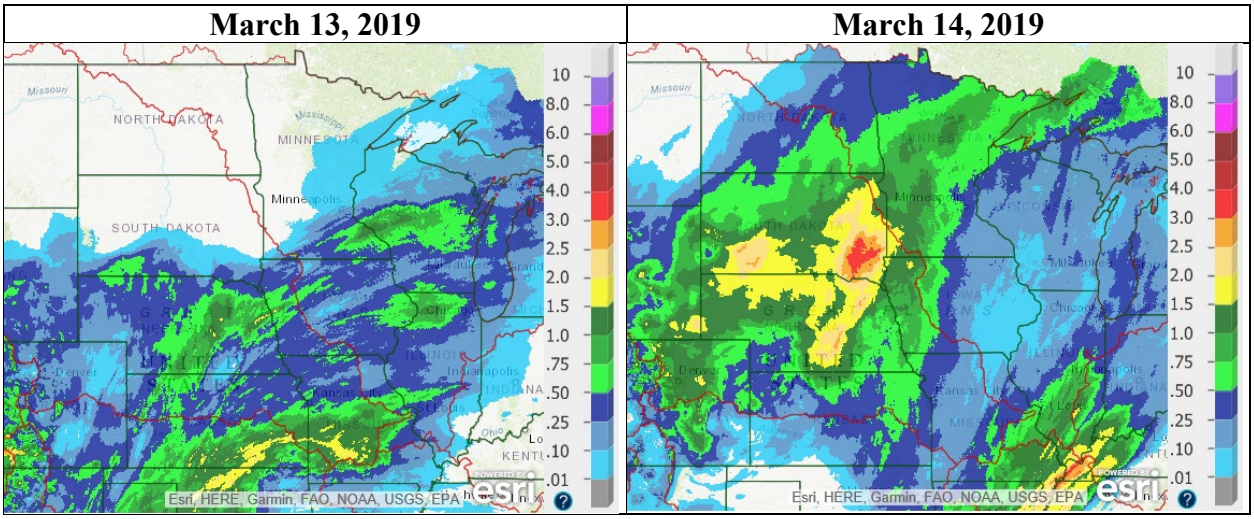


Figure 3. Daily precipitation reported at 6 a.m. on March 13 and 14, 2019. Source: National Weather Service Advanced Hydrologic Prediction Service. https://water.weather.gov/precip/

Daily rainfall totals estimated by the NWS quantitative precipitation estimate (QPE) routine are shown in **Figure 3**. Daily rainfall ending on the morning of March 13 ranged from 0.5 to 1.5 inches in central Nebraska. By the morning of March 14, additional heavy rainfall occurred throughout central and northern Nebraska, southern and southeastern South Dakota, and western Iowa. The heaviest rainfall totals ranged from 1.5 inches up to and in excess of 3 inches in southeastern South Dakota. **Table 1** lists some point rainfall reports in southeastern South Dakota, northwestern Iowa and Nebraska. The heaviest daily rainfall report among these locations was 2.89 inches in Yankton, SD. A few reports near Sioux Falls, SD indicated up to 5 inches of rainfall occurred.

Table 1. March 13-15, 2019 rainfall totals at locations in South Dakota, Iowa and Nebraska.

Location	March 13, 2019	March 14, 2019	March 15, 2019	Total
Yankton, SD	0.10	2.89	0.14	3.13
Sioux Falls, SD	1.91	0.58	0.00	2.49
Vermillion, SD	0.19	1.55	1.13	2.87
Sioux City, IA	1.63	0.18	0.00	1.81
Sioux Center, IA	1.03	0.94	0.00	1.97
O'Neill, NE	0.49	2.29	0.00	2.78
Norfolk, NE	1.85	0.41	0.00	2.26
Lincoln, NE	0.41	0.46	0.06	0.93
Omaha, NE	0.41	0.78	0.18	1.37

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. Precipitation as a percent of normal for the first half of March is shown in the left image of **Figure 4**, and mid-February to mid-March precipitation as a percent of normal is shown in the right image of **Figure 4**. March precipitation as a percent of normal is shown in the left image of **Figure 5**, and January-February-March precipitation as a percent of normal is shown in the right image of **Figure 5**. March precipitation was well-above normal (greater than 200%) over Colorado, Nebraska, southeastern South Dakota, and western Iowa. **Table 2** contains a list of January to March precipitation totals compared to normal precipitation totals. Total precipitation was two to three times the normal amount at many locations.

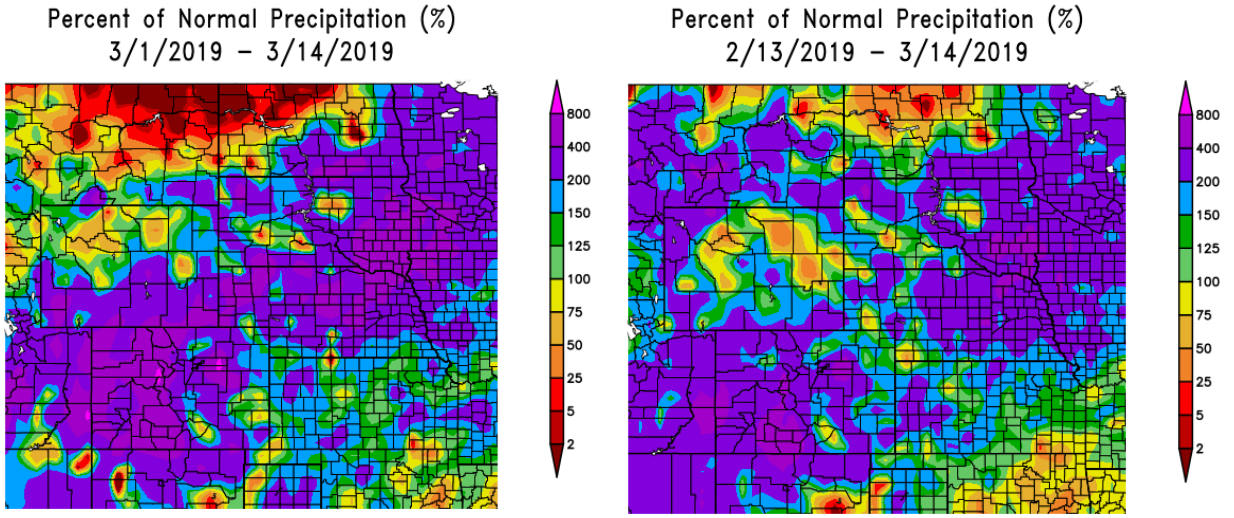


Figure 4. Percent of Normal Precipitation for March 1-14, 2019 and February 13 – March 14, 2019. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

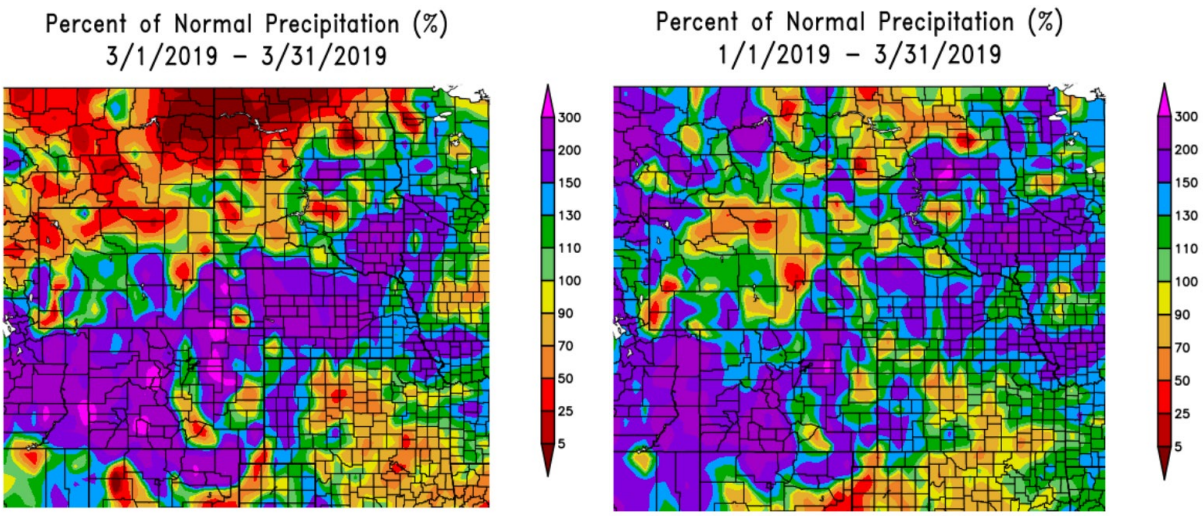


Figure 5. March 2019 and January-February-March 2019 Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 2. January – March 2019 precipitation totals compared to normal totals.

Location	January-March Precipitation inches	January-March Normal inches
Helena, MT	3.78	1.28
Great Falls, MT	4.19	1.93
Glasgow, MT	1.89	1.07
Billings, MT	3.42	2.07
Miles City, MT	0.62	1.04
Bismarck, ND	2.79	1.84
Pierre, SD	3.85	2.29
Aberdeen, SD	3.57	2.22
Watertown, SD	4.60	2.24
Mobridge, SD	3.47	1.66
Sioux Falls, SD	5.79	3.01
Mitchell, SD	4.42	1.64
Yankton, SD	4.68	3.08
Sioux City, IA	4.61	3.37
O'Neill, NE	5.00	2.82
Norfolk, NE	4.36	3.19
Omaha, NE	5.55	3.64
Lincoln, NE	5.03	3.41
Kansas City, MO	7.22	4.90

Temperature

Temperature departures for March are shown in degrees Fahrenheit (deg F) in the right image of **Figure 6**. Departures ranged from 6 to over 15 deg F BELOW normal in the upper Basin, and 3 to 9 deg F below normal in the lower Basin. January-February-March temperature departures, shown in the right image of **Figure 6**, were colder-than-normal over the entire Basin**.** In most of the upper Basin, departures ranged from 6 to 15 degrees below normal. These cold temperatures directly influenced the rapid formation of mountain and plains snowpack, as well as very deep soil frost depths. Temperatures were also below normal in the lower Basin, ranging from 3 to 9 deg F below normal.

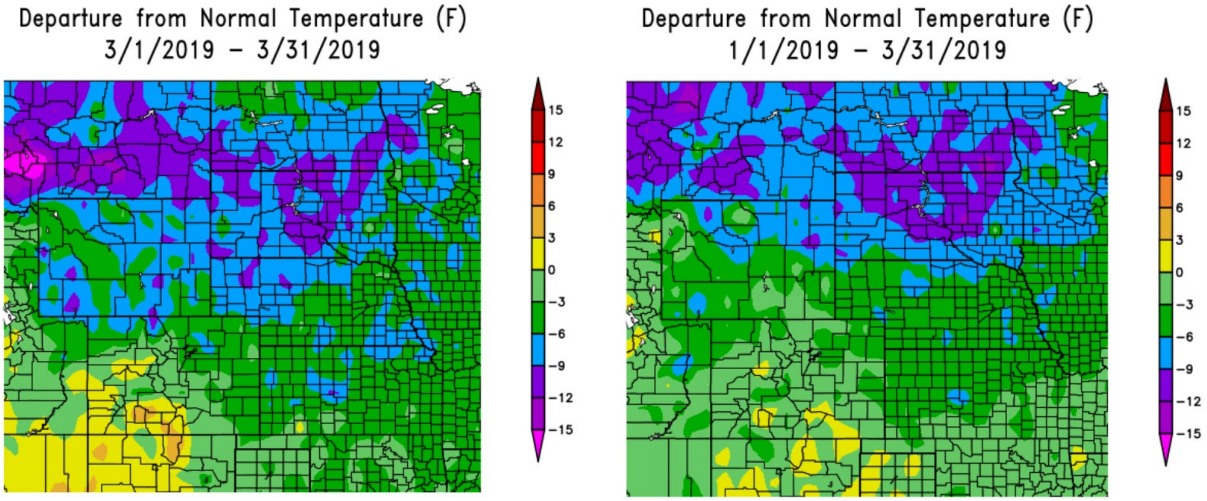


Figure 6. March 2019 and January-February-March 2019 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Frost Conditions

Soil frost is an important runoff factor as snow begins to melt. Frost depth is the depth of frozen ground from the soil surface. Soil frost acts as a barrier to snowmelt and rainfall infiltration into the soil. The deeper the depth of frost formation, the greater the barrier for water infiltration, and thus the higher the runoff potential. The depth of frost penetration or frost depth is shown in **Figure 7**. The NWS monitors frost depth at each of their NWS warning forecast office locations. The number under the station location denotes the number of inches of frost formation, while an "M" denotes a missing value. The **Figure 7** map shows that frozen ground has developed relatively deep in the upper Basin, and it is frozen at nearly all locations in the Missouri River Basin still. The deepest frost depth is 50 inches at Bismarck, ND (BRKN8). The depth at Sioux Falls (FSDS2) is 23 inches, not missing as indicated on the map. Due to the extensive and deep formation of frost in the Missouri Basin, spring 2019 runoff potential is higher than normal.

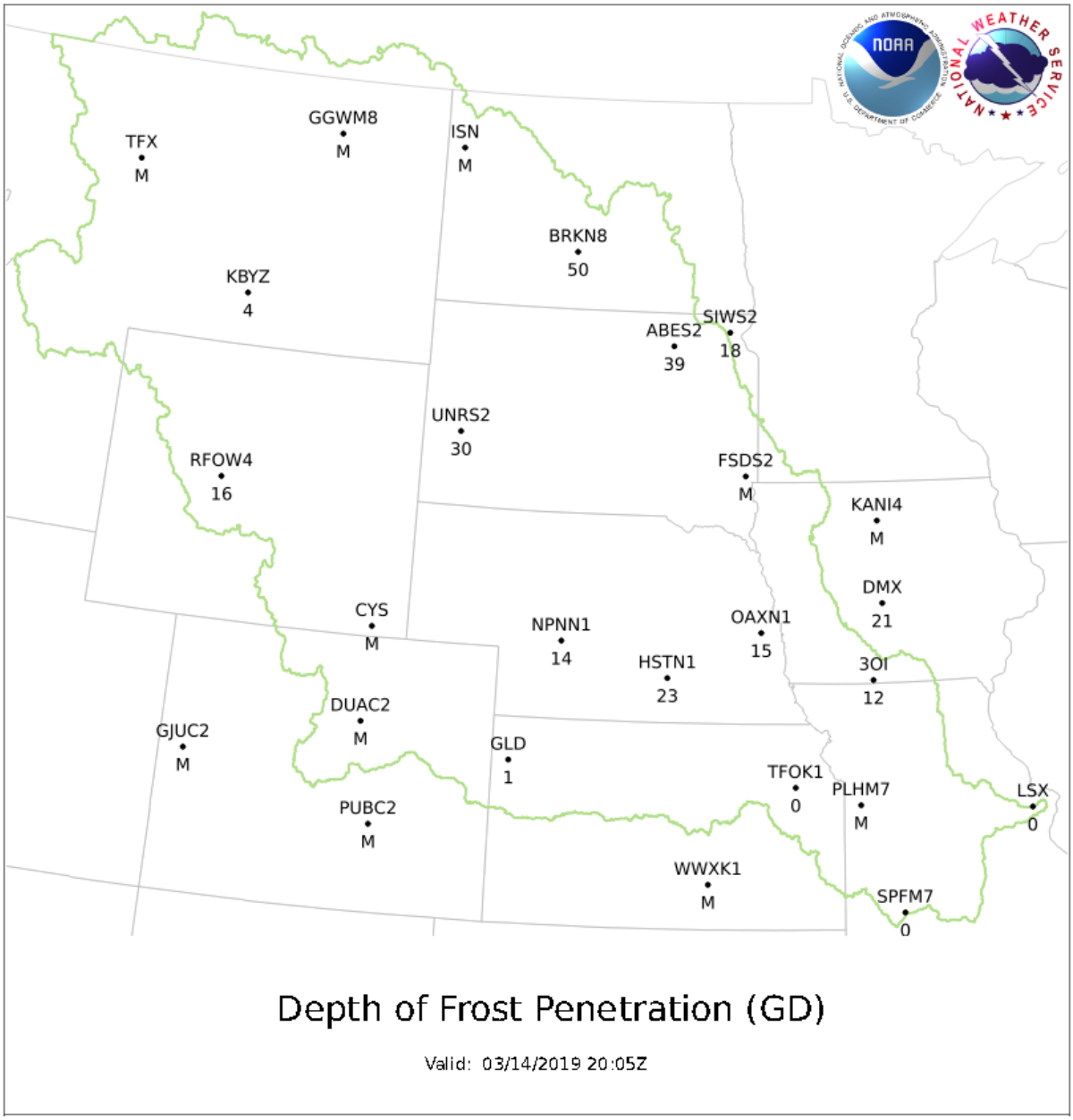
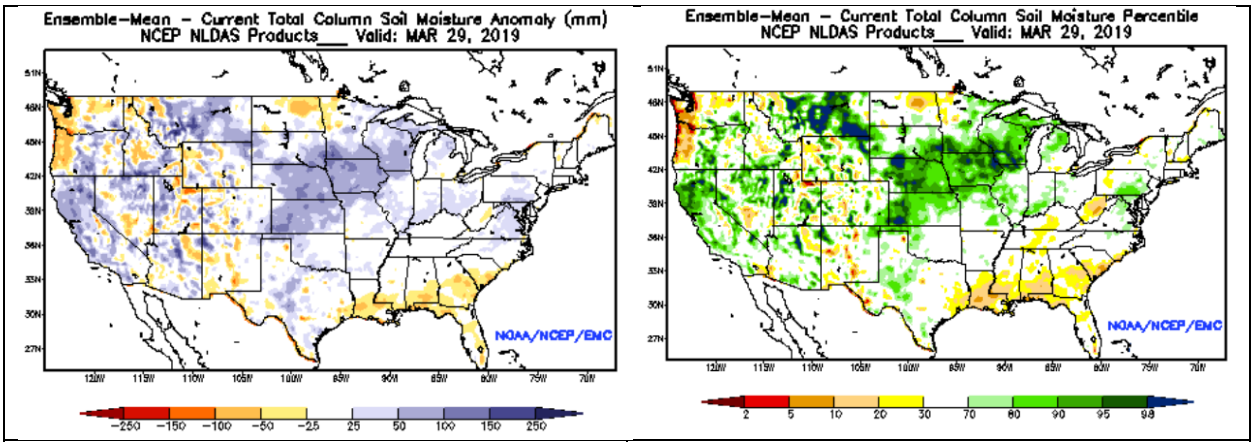


Figure 7. NWS frost depth (inches) as of March 14, 2019.

Soil Moisture

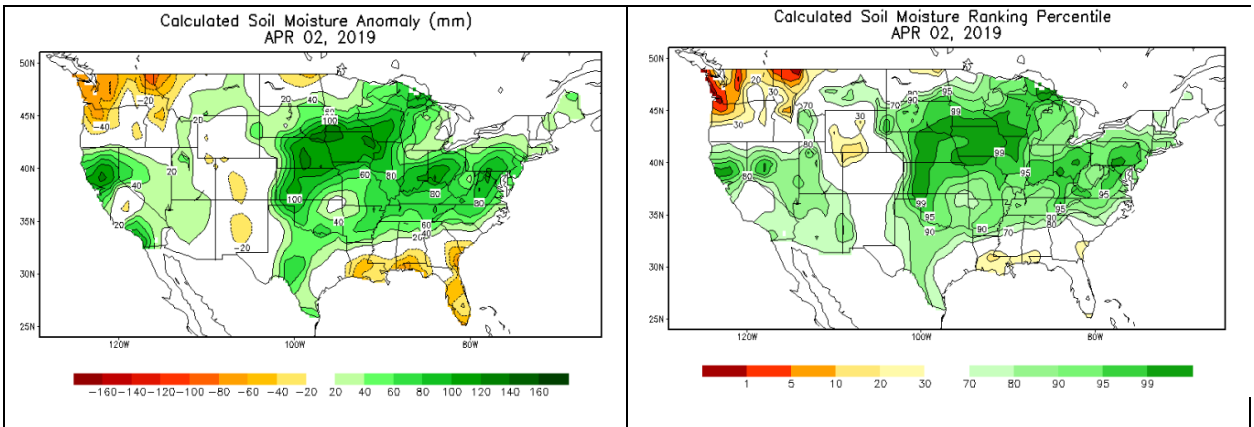
Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the soil moisture conditions will provide some insight into late winter and early spring runoff potential.

Figure 8 shows the March 29, 2019 NOAA NLDAS ensemble soil moisture anomaly and soil moisture percentile. **Figure 9** shows the April 02, 2019 NOAA CPC soil moisture anomaly and soil moisture percentile. Soil moisture conditions in both soil moisture maps show similar conditions. Soil moisture anomalies and percentiles are well-above normal in Montana, northeastern Wyoming, southern South Dakota, Nebraska, Iowa and Kansas. Soil moisture conditions are particularly wet in South Dakota, Nebraska, Iowa and Kansas, where percentiles are greater than the 90th percentile for wetness over much of the four states. Conditions are normal to slightly below normal over the rest of the Dakotas, Wyoming and Colorado. Spring runoff could potentially be above normal under normal winter precipitation and snowfall accumulations due to the above-normal soil moisture conditions.



Soil Moisture Anomaly (mm)	Soil Moisture Percentile

Figure 8. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/



Soil Moisture Anomaly (mm)	Soil Moisture Percentile

Figure 9. NOAA CPC Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA CPC. https://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml

Plains Snowpack

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. A common misperception is that the March-April

runoff is a result of plains snowmelt only. Historically, about 25% of annual runoff occurs in March and April, during the time when plains snow is melting, due to both melting snowpack and rainfall runoff. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more than a week in advance. Thus, the March-April runoff forecast is formulated based on existing plains snowpack and existing basin conditions and hydrologic forecasts, which for this year primarily includes long-term precipitation outlooks. At this time of year, plains snowpack is a good indicator for March-April runoff; however, as the snowpack reaches its ultimate peak accumulation, better forecasts of future runoff can be made.

Plains snowpack increased significantly in coverage over the upper Basin in early March. The National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC), modeled snow assessment from March 7 is shown in **Figure 10**, and the NOHRSC modeled snow assessment from March 14 is shown in **Figure 12**.

On March 7, 2019, plains snowpack was considered moderate in eastern Nebraska and western Iowa (2 to 3 inches of SWE) with some areas considered moderate to heavy (3 to 4 inches of SWE). Central Nebraska on March 7 contained light to moderate snowpack (1 to 2 inches of SWE). In South Dakota, SWE ranged from light (1 inch) in southern regions of the state to moderate to heavy (3 to 4 inches) in central portions of the state.

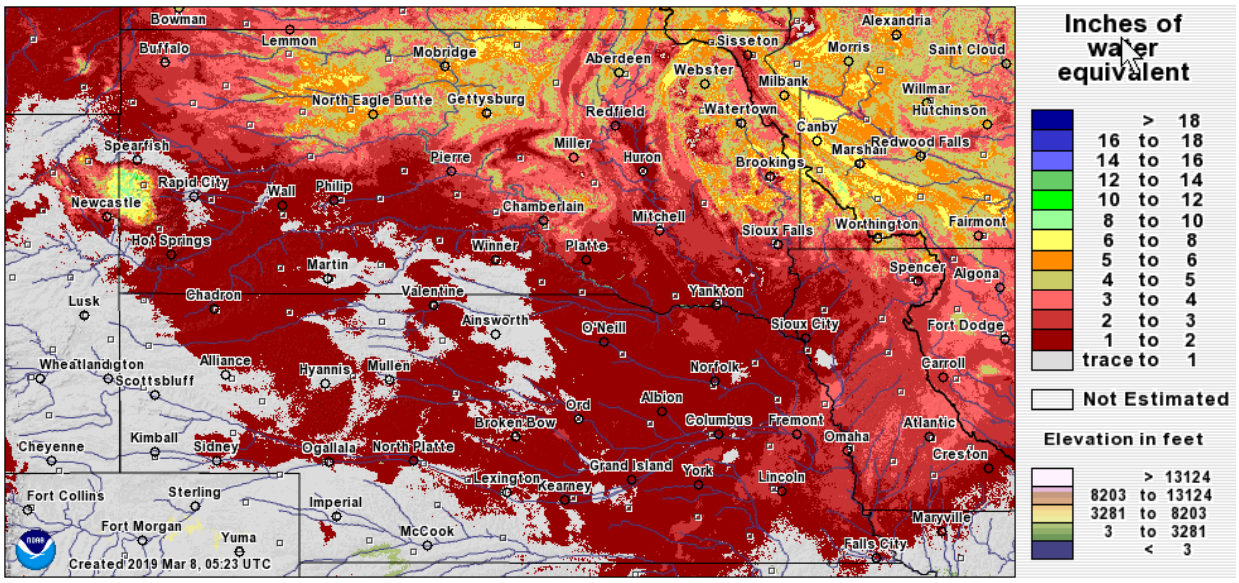


Figure 10. March 7, 2019 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

During the three-day period spanning March 13, 14 and 15, 2019, steady snowmelt occurred over southern South Dakota, Nebraska and Iowa. Most of the plains snowpack in these areas melted as a result of the warm temperatures, and the transfer of energy to the snowpack through rainfall. NOHRSC estimated between 2 and 4 inches of SWE melted March 13-15 in

southeastern South Dakota, northern and eastern Nebraska and western Iowa (**Figure 11**). In some areas in western Iowa and along the Nebraska-South Dakota state line, more than 4 inches of SWE may have melted from March 13-15.

The "Bomb Cyclone" storm that occurred March 13-15 also produced significant heavy snowfall in western Nebraska and western and central South Dakota. Significant snowfall amounts ranging from 8-12 inches occurred in Scottsbluff and Chadron, NE; Winner, Pierre and Mobridge SD; and Montpelier and Ashley, ND. The accumulated SWE estimated by the NOHRSC snow model on March 14 is shown in **Figure 12**. NOHRSC estimated 5 to 8 inches of SWE spread throughout central, northern and eastern South Dakota and southern North Dakota. The total accumulated SWE in these areas began melting in eastern South Dakota on March 15, and in central South Dakota March 20. By March 31 (**Figure 13**), much of the seasonal plains snowpack had melted in South Dakota, with some SWE ranging from 2 to 5 inches remaining in areas of north central South Dakota.

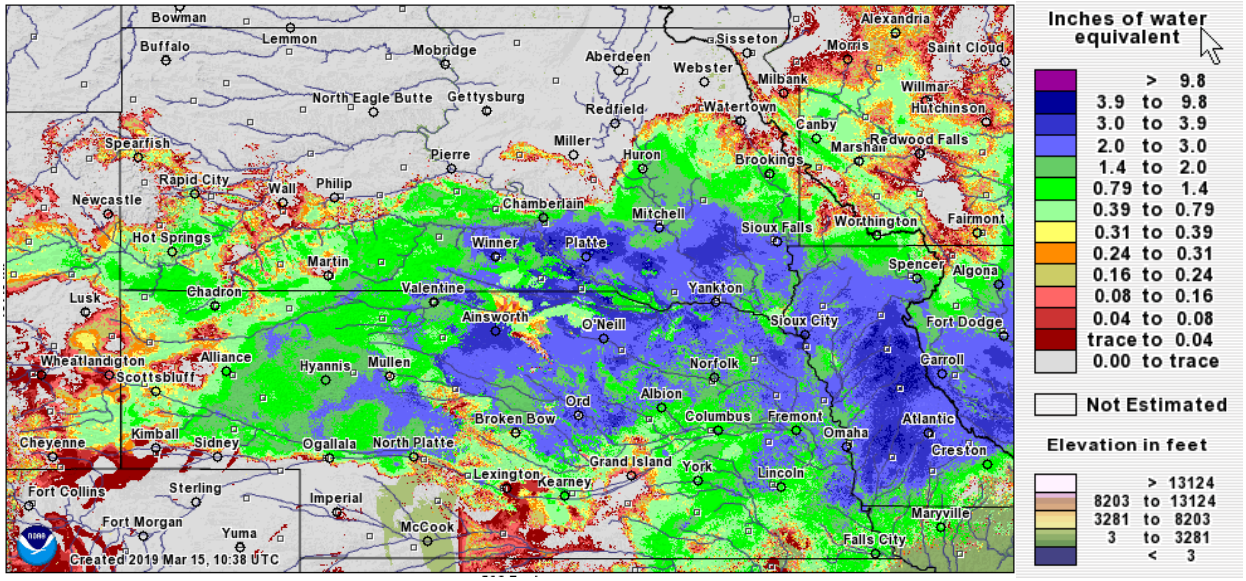


Figure 11. March 13-15, 2019 NOHRSC model plains snow water equivalent melt as inches of water. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

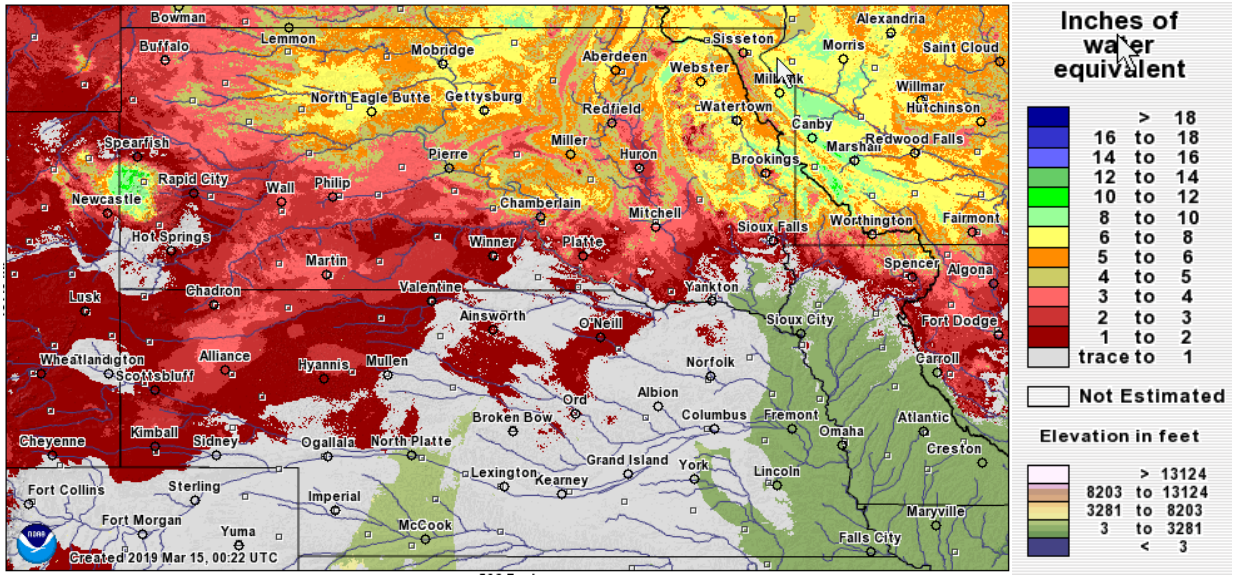


Figure 12. March 14, 2019 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

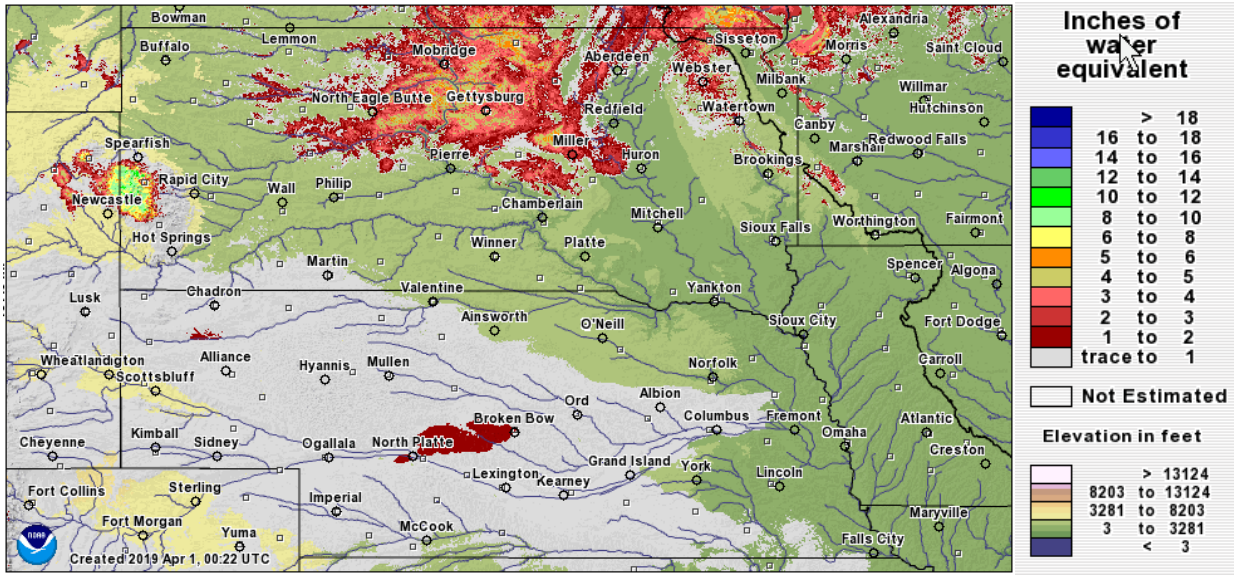


Figure 13. March 31, 2019 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

MRBWM obtains measurements of plains snow depth and SWE every two weeks while plains snowpack persists in the upper Missouri Basin. The most recent measurements were taken during the week of March 25, and are posted to the MRBWM website at: http://www.nwd-mr.usace.army.mil/rcc/snowsurvey/snowsurvey.html.

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reservoir reaches. It is typically NOT a factor influencing runoff at the beginning of a calendar year.

Figure 14 includes time series plots of the average mountain SWE beginning on October 1, 2018 based on the NRCS SNOTEL data for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of April 1, the Corps of Engineers computed an average mountain SWE in the Fort Peck reservoir reach of 15.3 inches, which is 97% of average based on the 1981-2010 average SWE for the Fort Peck reach. In the reservoir reach between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 12.9 inches, which is 93% of average based on the 1981-2010 average SWE for the Garrison reach. Typically by April 1, 97% of the total accumulation has occurred.

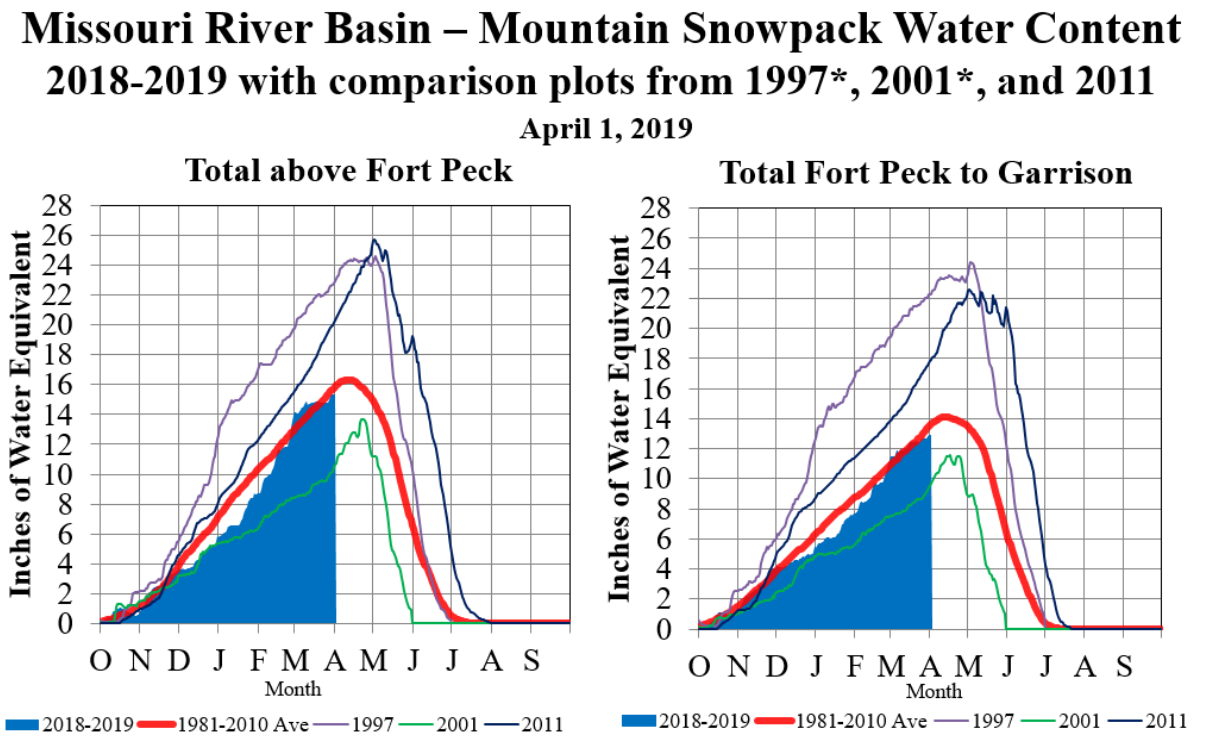


Figure 14. Mountain snowpack water content on April 1, 2019 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO Outlook indicates that El Nino conditions are present. Weak El Niño conditions are expected to continue through the Northern Hemisphere spring (~80% chance) and summer (~60% chance).

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

With regard to future weather, the CPC precipitation outlook for April 10-16 (**Figure 15**) is indicating increased chances for above-normal precipitation over most of the Basin, along with increased chances for below-normal temperatures.

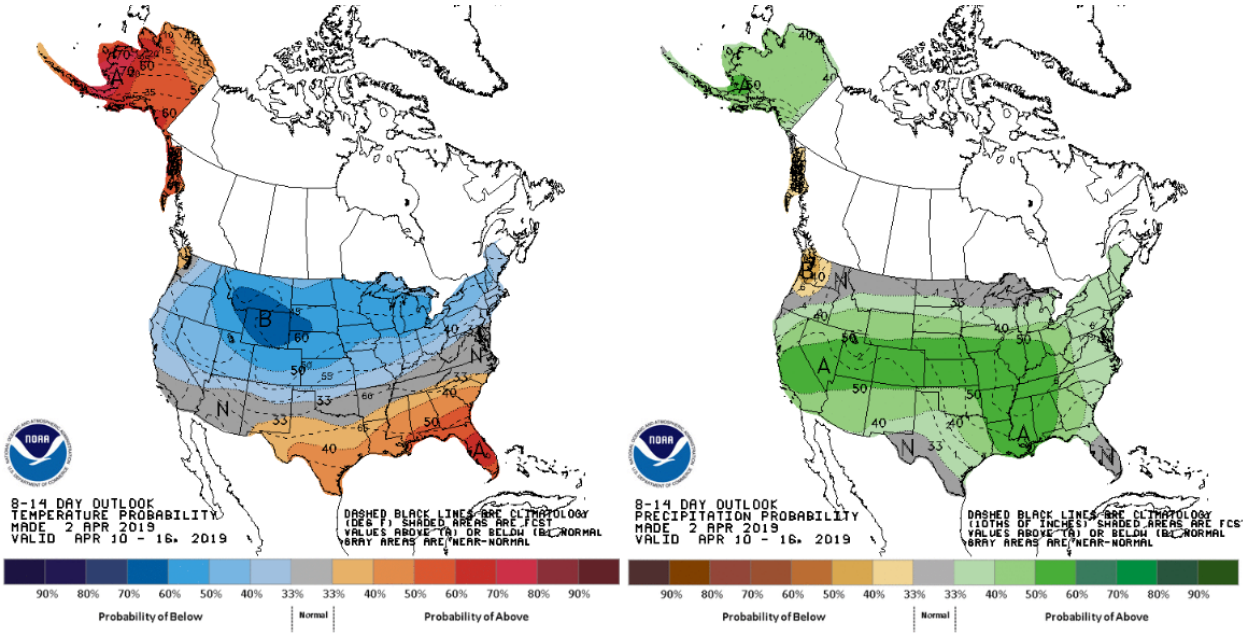


Figure 15. CPC 8-14 Day temperature and precipitation outlooks through April 16, 2019.

The April CPC outlooks in **Figure 16** indicate increased chances for above-normal temperatures in most of the Basin. With regard to precipitation, the April outlook indicates increased chances for above-normal precipitation over most of the lower Basin with areas of equal and below-normal chances in Montana and North Dakota.

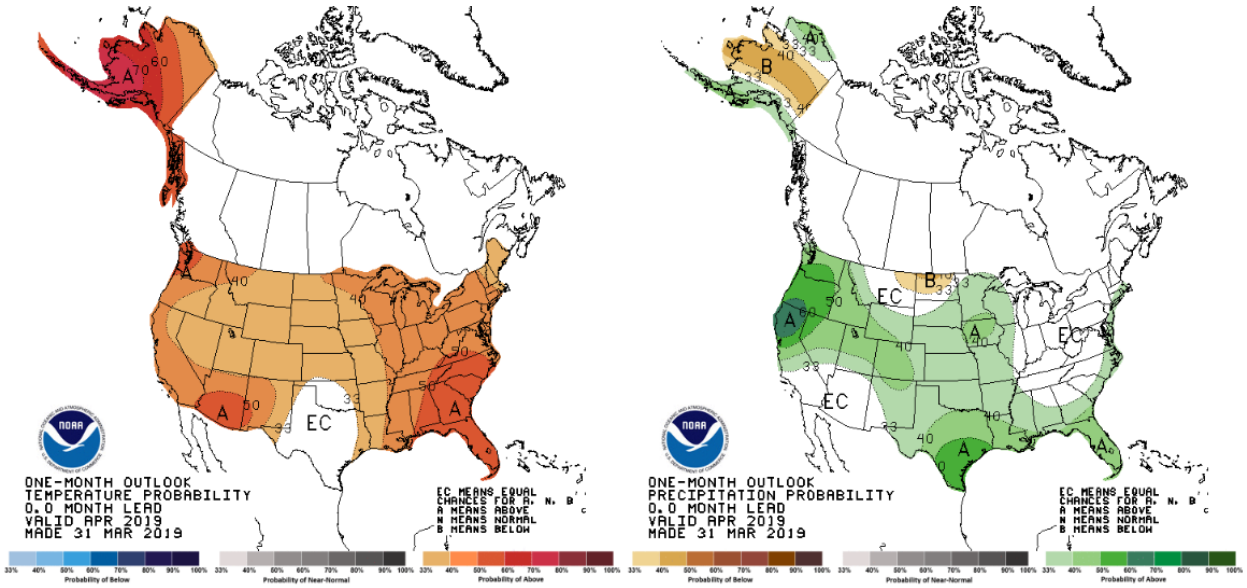


Figure 16. CPC April 2019 temperature and precipitation outlooks.

During the May-June-July 2019 period, the CPC outlooks in **Figure 17** indicate increased chances for below-normal temperatures in South Dakota, Nebraska, Kansas, and western Iowa, with equal chances in the remainder of the Missouri Basin. With regard to the precipitation outlook, there are increased chances for precipitation in most of the Basin. There are equal chances for precipitation in Montana and North Dakota.

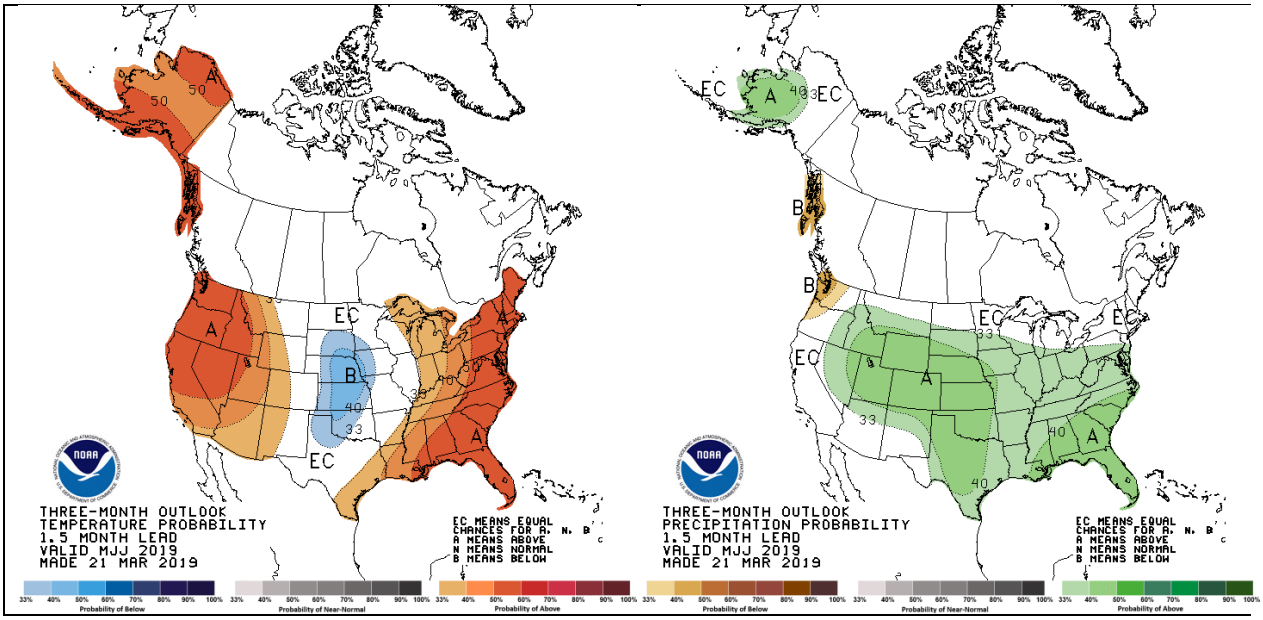


Figure 17. CPC May-June-July 2019 temperature and precipitation outlooks.

During the August-September-October 2019 period, CPC outlooks in **Figure 18** indicate increased chances for above-normal temperatures over the entire Basin. The precipitation

outlook indicates a slight increase in chances for above-normal precipitation over the lower Basin.

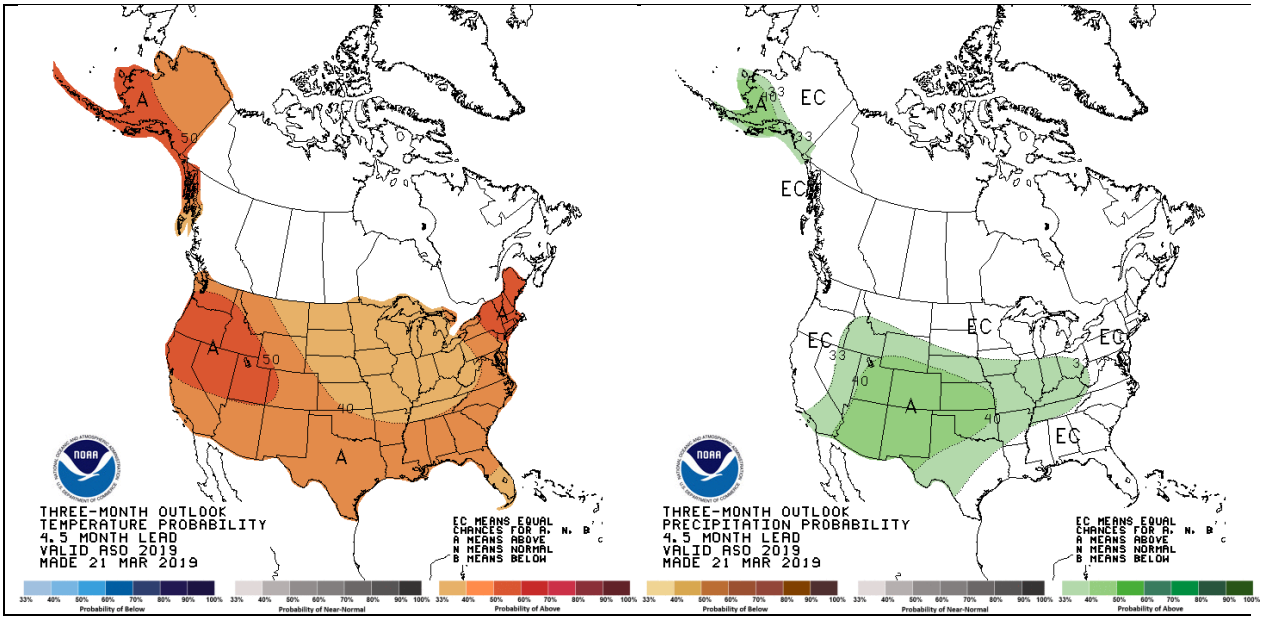


Figure 18. CPC August-September-October 2019 temperature and precipitation outlooks.

The November-December 2019-January 2020 outlooks in **Figure 19** indicate an increase in the chances for above-normal temperatures over the entire Basin. In regard to precipitation, there are equal chances throughout the Missouri Basin.

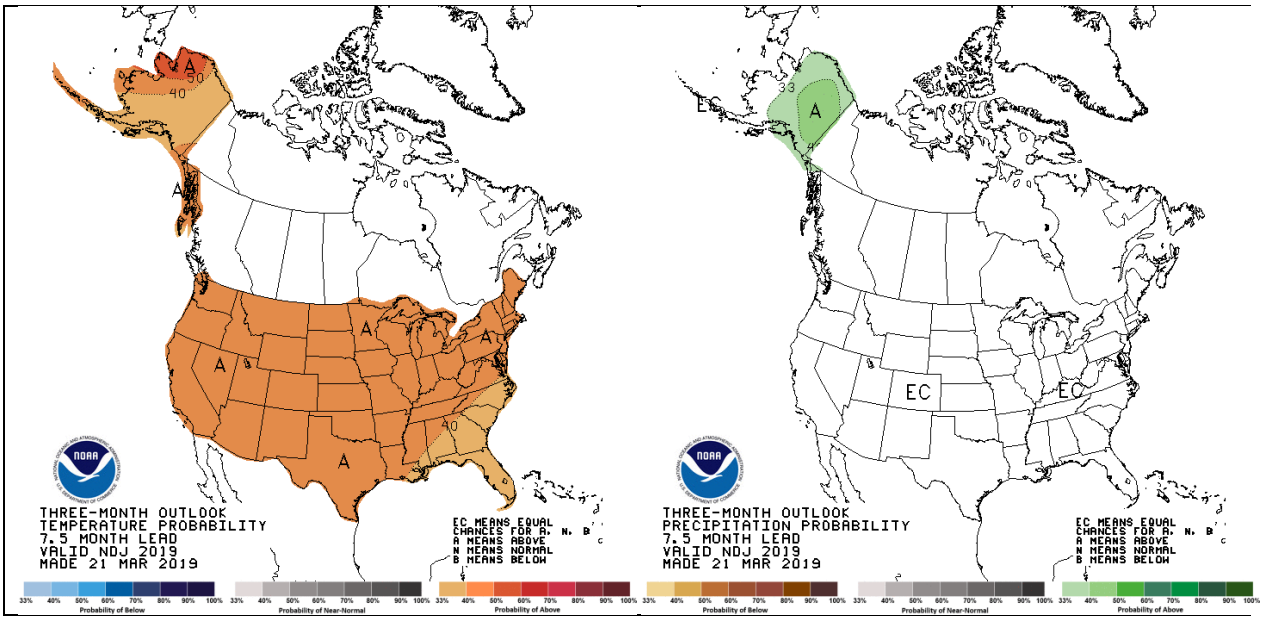
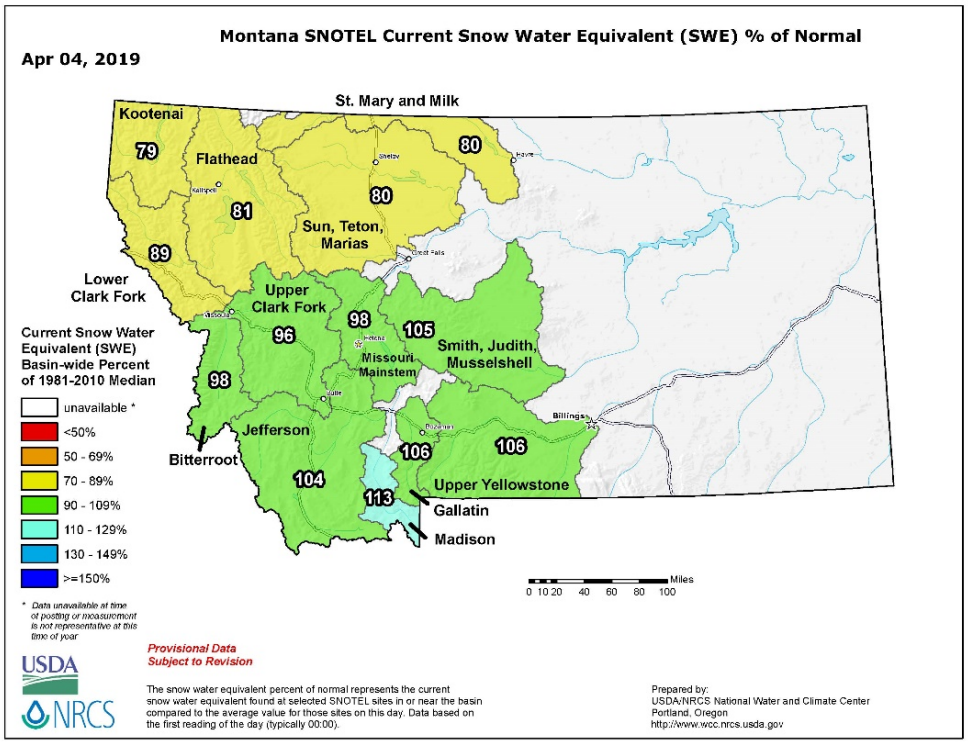


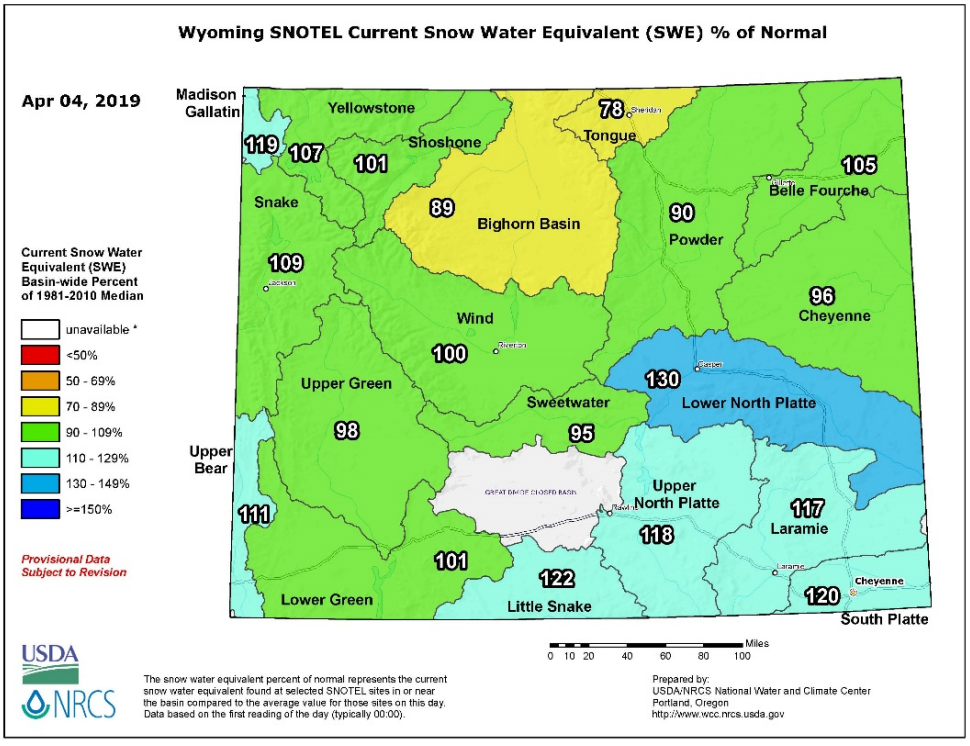
Figure 19. CPC November-December 2019-January 2020 temperature and precipitation outlooks.

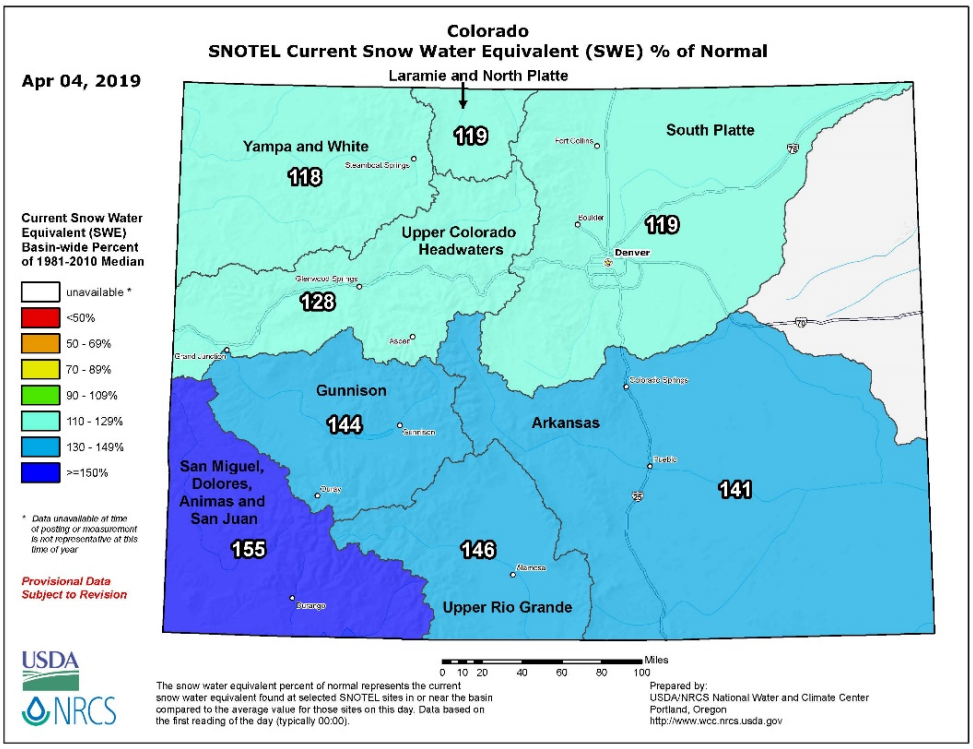
Summary

In summary, the 2019 calendar year runoff forecast is **38.2 MAF, 151% of average**. The April forecast is an increase of 9.8 MAF since March 1. This increase is due to the additional plains snowpack and March precipitation. The 2019 calendar year runoff forecast above Gavins Point Dam is **31.7 MAF, 138% of average**.

Additional Figures






Colorado
SNOTEL Current Snow Water Equivalent (SWE) % of Normal
Apr 04, 2019
Laramie and North Platte
119
Yampa and White
118
South Platte
119
Upper Colorado Headwaters
128
Gunnison
144
Arkansas
141
San Miguel, Dolores, Animas and San Juan
155
146
Upper Rio Grande
Current Snow Water Equivalent (SWE) Basin-wide Percent of 1981-2010 Median
unavailable *
<50%
50 - 69%
70 - 89%
90 - 109%
110 - 129%
130 - 149%
>=150%
* Data unavailable at time of posting or measurement is not representative at this time of year
Provisional Data Subject to Revision
Miles
0 10 20 40 60 80 100
The snow water equivalent percent of normal represents the current snow water equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).
Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

USDA NRCS National Water & Climate Center
*** - DATA CURRENT AS OF: April 04, 2019 10:34:03 AM**
- Based on April 01, 2019 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow (2)	APR-JUL	81	84	98	88	74	63	97
	APR-SEP	94	84	115	103	86	74	112
St. Mary R at Intl Boundary (2)	APR-JUL	345	79	445	385	310	250	435
	APR-SEP	410	81	515	450	365	300	505
Lima Reservoir Inflow (2)	APR-JUL	86	115	112	97	75	60	75
	APR-SEP	94	118	122	106	82	66	80
Clark Canyon Reservoir Inflow (2)	APR-JUL	94	93	141	113	75	47	101
	APR-SEP	117	98	172	139	95	62	120
Jefferson R nr Three Forks (2)	APR-JUL	715	97	1030	845	585	400	740
	APR-SEP	765	96	1120	910	620	405	800
Hebgen Lake Inflow (2)	APR-JUL	390	105	460	420	360	320	370
	APR-SEP	490	104	575	525	455	405	470
Ennis Lake Inflow (2)	APR-JUL	650	104	780	705	595	520	625
	APR-SEP	800	103	960	865	740	645	775
Missouri R at Toston (2)	APR-JUL	1810	101	2350	2030	1590	1270	1790
	APR-SEP	2070	100	2710	2330	1800	1420	2070
Smith R bl Eagle Ck (2)	APR-JUL	107	101	159	128	86	55	106
	APR-SEP	117	101	180	143	91	54	116
Gibson Reservoir Inflow (2)	APR-JUL	285	72	365	320	255	205	395
	APR-SEP	320	73	410	355	285	230	440
Marias R nr Shelby (2)	APR-JUL	245	68	375	295	193	116	360
	APR-SEP	255	68	390	310	197	115	375

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	APR-JUL	59	100	67	62	55	50	59
	APR-SEP	74	100	85	79	70	64	74
Wind R ab Bull Lake Ck	APR-JUL	425	93	565	480	370	285	455
	APR-SEP	450	92	605	515	385	295	490
Bull Lake Ck nr Lenore (2)	APR-JUL	134	96	167	147	121	101	139
	APR-SEP	163	96	200	179	146	123	169
Boysen Reservoir Inflow (2)	APR-JUL	555	91	910	695	410	197	610
	APR-SEP	595	89	975	750	440	215	665
Greybull R at Meeteetse	APR-JUL	121	92	183	146	96	59	131
	APR-SEP	162	92	235	192	132	88	177
Shell Ck nr Shell	APR-JUL	43	78	58	49	37	28	55
	APR-SEP	53	80	70	60	46	37	66
Bighorn R at Kane (2)	APR-JUL	720	86	1250	935	505	186	840
	APR-SEP	755	83	1320	985	525	184	905
NF Shoshone R at Wapiti	APR-JUL	500	109	585	535	465	415	460
	APR-SEP	560	109	660	600	520	460	515
SF Shoshone R nr Valley	APR-JUL	220	102	265	240	200	173	215
	APR-SEP	250	102	305	275	230	197	245
Buffalo Bill Reservoir Inflow	APR-JUL	715	106	870	780	650	555	675
	APR-SEP	790	106	965	860	720	615	745
Bighorn R nr St. Xavier (2)	APR-JUL	1280	93	1910	1540	1020	645	1380
	APR-SEP	1330	91	2030	1610	1040	625	1460
Little Bighorn R nr Hardin	APR-JUL	57	58	107	77	37	6.6	98
	APR-SEP	66	59	122	89	43	9.6	111
Tongue R nr Dayton (2)	APR-JUL	56	65	83	67	45	29	86
	APR-SEP	66	67	96	78	54	36	98
Tongue River Reservoir Inflow (2)	APR-JUL	103	53	205	143	62	2.8	193
	APR-SEP	121	56	225	163	78	14.8	215
NF Powder R nr Hazelton	APR-JUL	6.9	76	10.5	8.4	5.5	3.4	9.1
	APR-SEP	7.5	76	11.2	9.0	6.0	3.9	9.9
Powder R at Moorhead	APR-JUL	136	77	280	194	79	1.00	177
	APR-SEP	150	77	295	210	92	7.0	196
Powder R nr Locate	APR-JUL	155	78	310	220	92	1.00	199

	APR-SEP	169	77	330	235	103	6.4	220

PRELIMINARY RAPID VALLEY UNIT FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Deerfield Reservoir Inflow (2)	APR-JUL	4.5	87	7.5	5.7	3.3	1.53	5.2
Pactola Reservoir Inflow (2)	APR-JUL	17.5	80	30	23	12.4	4.8	22

PRELIMINARY PLATTE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
North Platte R nr Northgate (2)	APR-JUL	290	129	405	335	245	173	225
	APR-SEP	320	128	450	375	265	190	250
Encampment R nr Encampment (2)	APR-JUL	174	135	225	195	153	122	129
	APR-SEP	185	134	240	205	163	130	138
Rock Ck ab King Canyon Cnl nr Arlington	APR-JUL	56	114	70	61	50	42	49
	APR-SEP	59	113	73	65	53	44	52
Seminoe Reservoir Inflow (2)	APR-JUL	925	129	1250	1060	795	600	715
	APR-SEP	995	129	1340	1140	855	650	770
Sweetwater R nr Alcova	APR-JUL	47	80	78	60	34	15.1	59
	APR-SEP	50	78	84	64	37	16.5	64
La Prele Ck nr Douglas	APR-JUL	29	146	42	34	24	16.3	19.9
	APR-SEP	29	146	42	34	24	16.0	19.9
North Platte R bl Glendo Reservoir (2)	APR-JUL	1000	122	1450	1180	815	545	820
	APR-SEP	1040	122	1510	1230	850	570	850
North Platte R bl Guernsey Reservoir (2)	APR-JUL	1010	123	1480	1200	820	540	820
	APR-SEP	1050	124	1530	1240	850	565	850
Laramie R and Pioneer Cnl nr Woods Lg (2)	APR-JUL	154	134	205	175	134	105	115
	APR-SEP	169	134	225	190	147	114	126
Little Laramie R nr Filmore	APR-JUL	60	118	78	67	53	42	51
	APR-SEP	65	118	84	73	57	46	55

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
May 2019 Calendar Year Runoff Forecast
May 7, 2019

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

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

April runoff for the upper Basin above Sioux City was 7.8 MAF, 270% of average, and the 3rd highest April runoff summation in the 121 years of record-keeping. Runoff in the Sioux City reach was 2.3 MAF, the 2nd highest April runoff, following only 2.4 MAF in 1997. The total March-April runoff for the upper Basin was 18.7 MAF, which is greater than the previous highest March-April runoff volume of 15.9 MAF, occurring in 1952. Finally, January-April accumulated runoff to date in the upper Basin was 20.7 MAF, greater than the record high 20.2 MAF that occurred in 1997. For reference, the next highest January-April accumulated runoff was 18.2 MAF in 1952 followed by 17.7 MAF in 2011. The Fort Randall, Gavins Point and Sioux City reaches, which also received record high accumulated runoff to date, were large contributors to this upper Basin record.

2019 Calendar Year Forecast Synopsis

The 2019 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA is **43.2 MAF, 170% of average**. The forecast increased 5.0 MAF from the April 1 forecast due in part to the observed April runoff. The 2019 calendar year runoff forecast above Gavins Point Dam,

which does not include runoff from the James, Vermillion and Big Sioux rivers, is **33.7 MAF, 146% of average**. Soil conditions continue to be wet (and in some areas, very wet) in the Missouri Basin. The plains snow has all melted in the upper Basin. Recent precipitation outlooks have indicated stronger likelihoods for above-normal precipitation over the next several months.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 8 months, expected inflow could range from the **52.2 MAF** upper basic forecast to the **35.2 MAF** lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that nine months are being forecast for this May 1 forecast (4 months observed/8 months forecast), the range of possible wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is very large, and is attributed to all 6 reaches for the entire year. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for April 30, 2019 is shown in **Figure 1**. The drought monitor is available at http://droughtmonitor.unl.edu/. The Drought Monitor shows some isolated areas of Abnormal Dryness (D0) present in the northwestern and northeastern Montana, northwestern North Dakota, and north central Wyoming. Moderate Drought (D1) conditions are present in the Bighorn Range of north central Wyoming.

The Seasonal Drought Outlook in **Figure 2**, which extends through the end of July, indicates there is not likely to be any classification change across most of the Missouri Basin. Some drought improvement is likely to occur over the Bighorn Range in Wyoming as the mountain snow melts during the spring and summer.

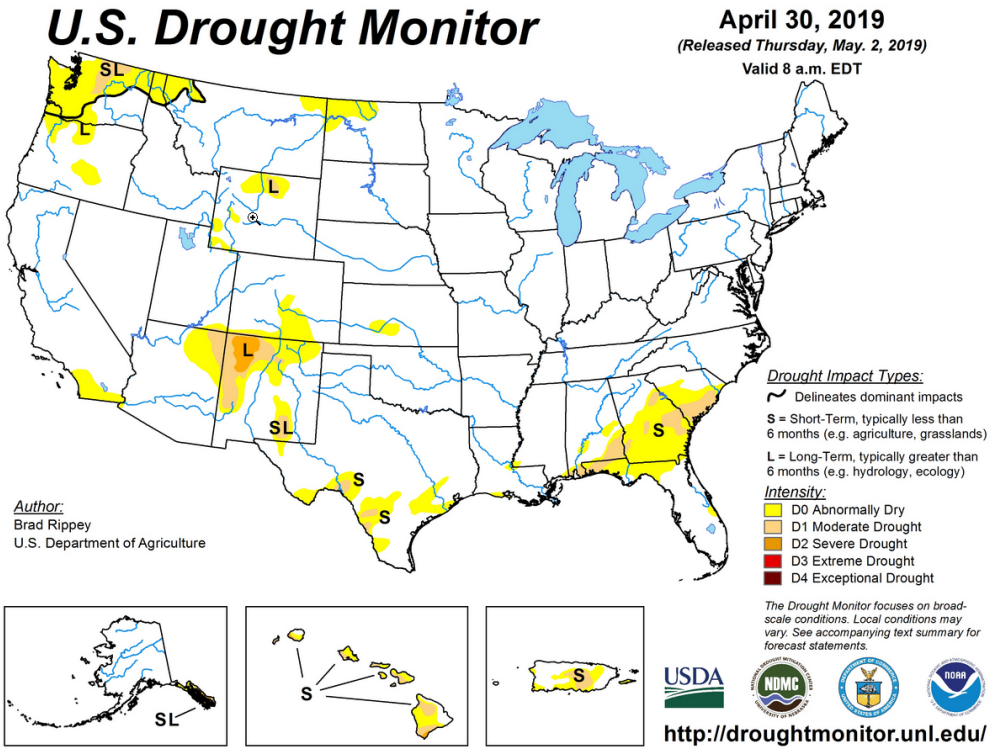


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for April 30, 2019.

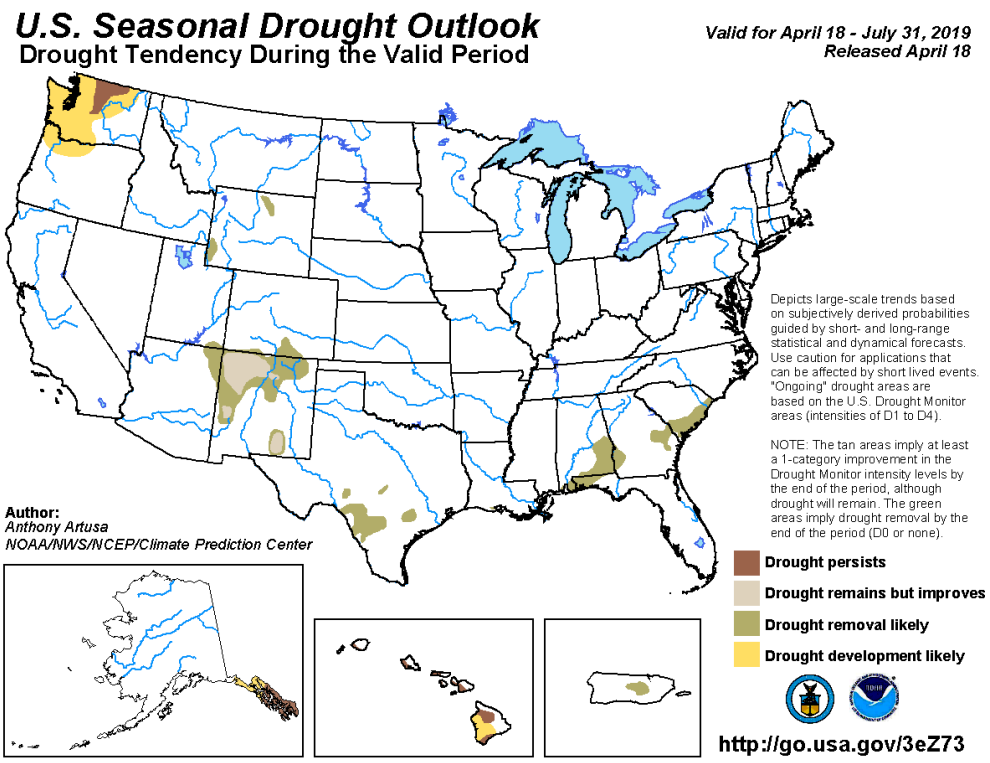


Figure 2. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. Precipitation as a percent of normal in April is shown in the left image of **Figure 3**, and February-March-April precipitation as a percent of normal is shown in the right image of **Figure 3**. April precipitation was a mixture of above- and below-normal precipitation. The northern Rockies and central and northeastern Montana received above-normal precipitation. Also, a very large spring storm brought above-normal precipitation to much of South Dakota, southwestern Minnesota and northwestern Iowa. In contrast, most of the lower Basin received below-normal precipitation. Precipitation was less than 50 percent of normal in southern and eastern Nebraska and southwestern Iowa.

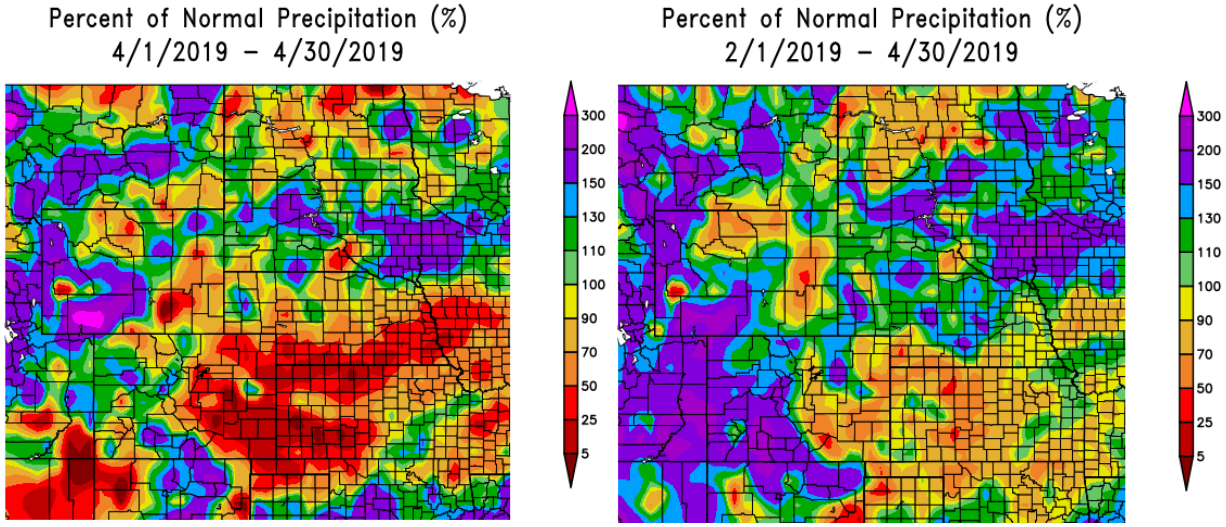


Figure 3. April 2019 and February-March-April 2019 Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

During the February-March-April period, the right image of **Figure 3** shows the wetter-than-normal pattern in the mountainous west, as well as northern Nebraska and South Dakota. Precipitation in other areas of the lower Basin has been mixed.

Temperature

Temperature departures for April are shown in degrees Fahrenheit (deg F) in the right image of **Figure 4**. Departures ranged from normal to slightly below normal throughout the upper Basin. Temperatures were about 2 to 4 deg F below normal in eastern South Dakota and eastern North Dakota. Temperatures in the lower Basin were normal to 4 deg F above normal. February-March-April temperature departures, shown in the right image of **Figure 4** show the much colder-than-normal temperature pattern that impacted much of the Missouri Basin in February and March**.** In most of the upper Basin, departures ranged from 6 to over 10 degrees below normal. These cold temperatures directly influenced the continued formation of mountain and plains snowpack in February, March, and intermittently during April. Very cold temperatures in February also caused the formation of very deep soil frost depths.

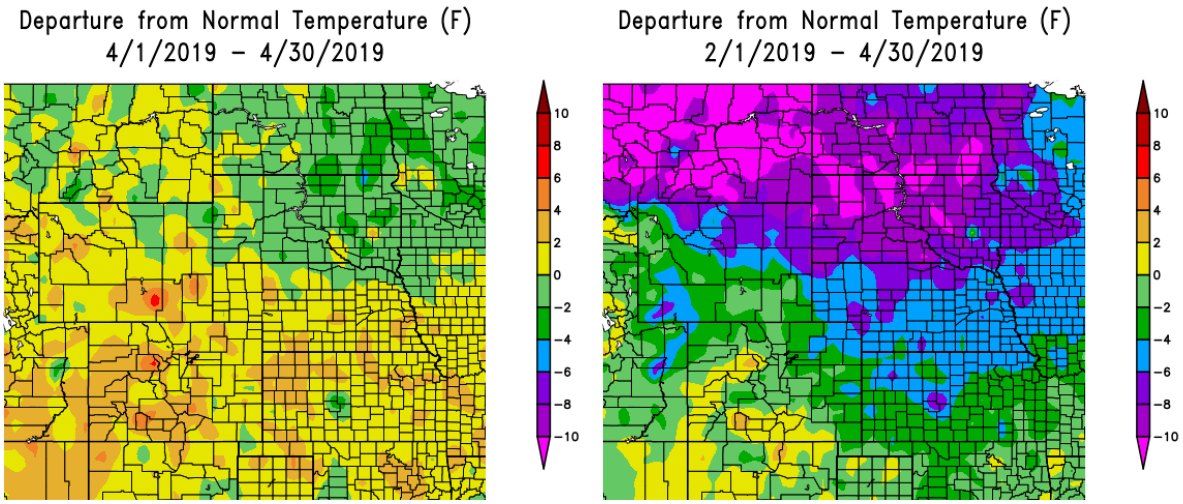


Figure 4. April 2019 and February-March-April 2019 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Frost Conditions

Soil frost is an important runoff factor as snow begins to melt. Frost depth is the depth of frozen ground from the soil surface. Soil frost acts as a barrier to snowmelt and rainfall infiltration into the soil. The deeper the depth of frost formation, the greater the barrier for water infiltration, and thus the higher the runoff potential. The depth of frost penetration or frost depth is shown in **Figure 5**. The NWS monitors frost depth at each of their NWS warning forecast office locations. At this time the NWS is indicating that all measureable soil frost has thawed.

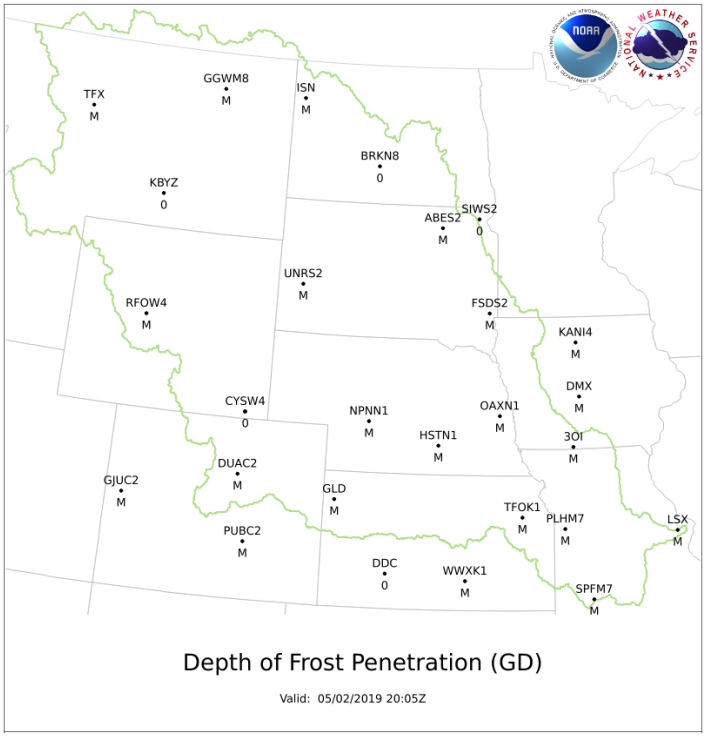


Figure 5. NWS frost depth (inches) as of May 2, 2019.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 6 shows the May 1, 2019 NOAA NLDAS ensemble soil moisture anomaly and soil moisture percentile. **Figure 7** shows the May 4, 2019 NOAA CPC soil moisture anomaly and soil moisture percentile. Based on the NLDAS soil moisture percentile map, soils are very wet in Montana, northeastern Wyoming, southeastern South Dakota, southwestern Minnesota, and northwestern Iowa. Based on the CPC map, soil moisture is wettest in northeastern Nebraska, southeastern South Dakota, Minnesota and northern Iowa.

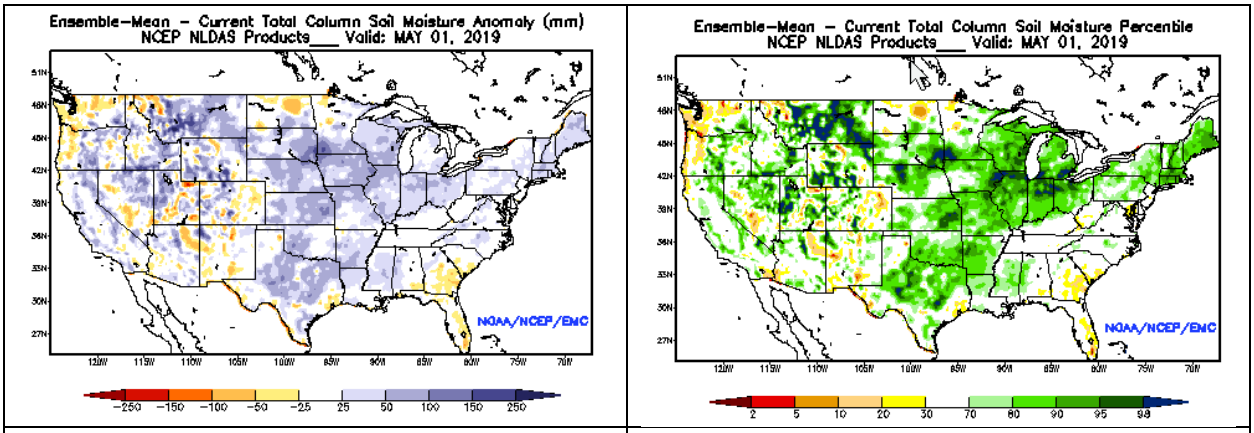


Figure 6. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

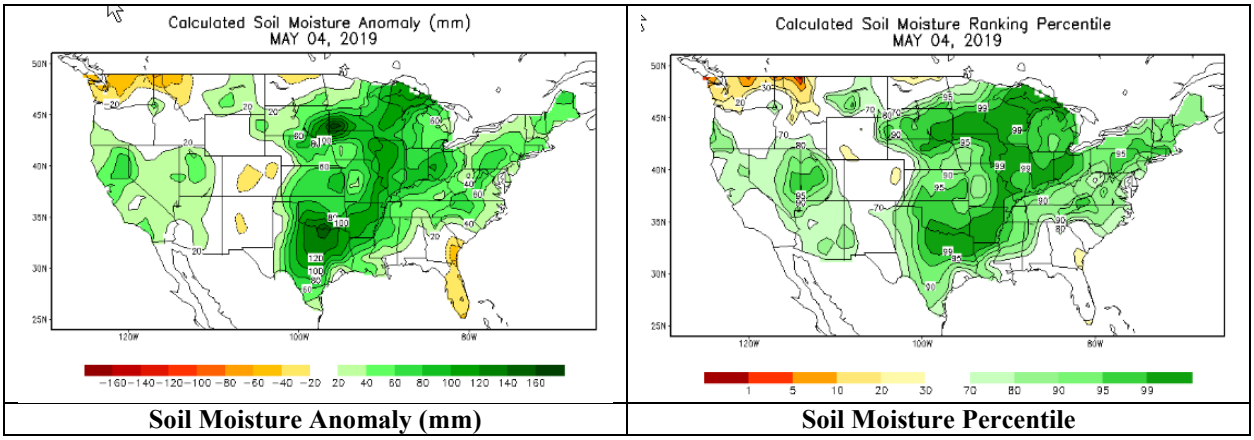


Figure 7. NOAA CPC Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA CPC. https://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml

Plains Snowpack

Much of the heavy plains snowpack in North Dakota and South Dakota had melted by early April; however, some additional heavy plains snowfall occurred April 10 – 13. April snowfall amounts, resulting primarily from the April 10 – 13 storm, included 25.0 inches at Watertown, 16.1 inches at Pierre, 17.5 inches at Webster, and 20.7 inches at Huron. The National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC), modeled snow assessment from April 13 is shown in **Figure 8**. SWE amounts ranged from 1 to 3 inches, and potentially greater than 3 inches in eastern South Dakota. This snow cover melted by April 18.

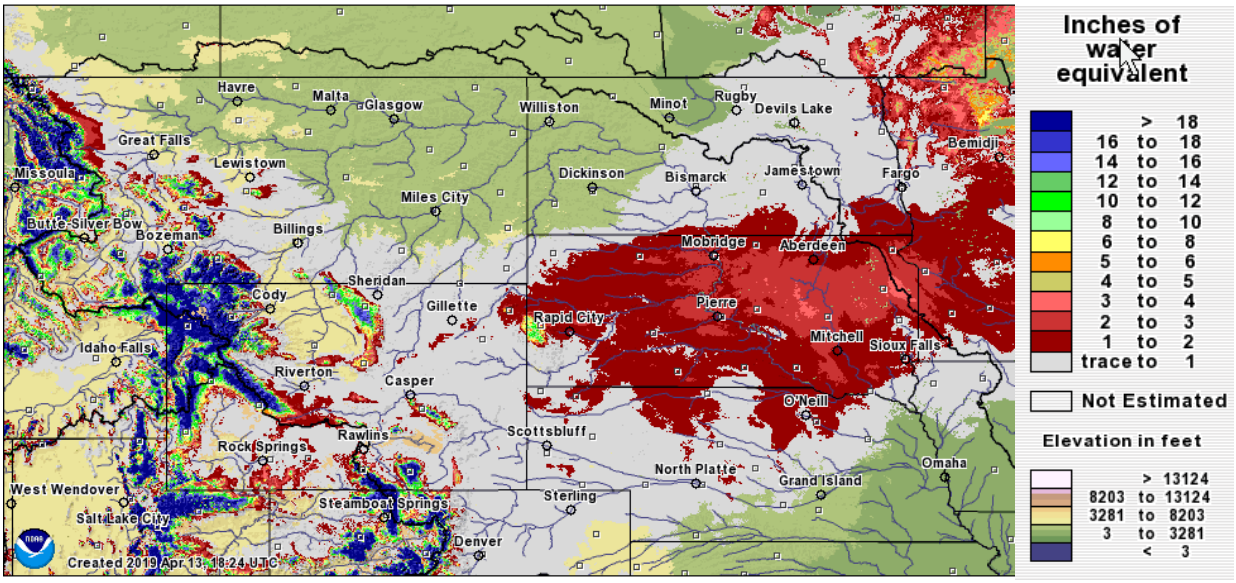


Figure 8. April 13, 2019 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Some additional moderate snowfall occurred near the end of April in southern Montana, Wyoming and western South Dakota. Snowmelt from the late-April snow mostly infiltrated into the soil because the soils had thawed prior to the snowfall. The remaining plains snowpack on May 1, 2019 is shown in **Figure 9**.

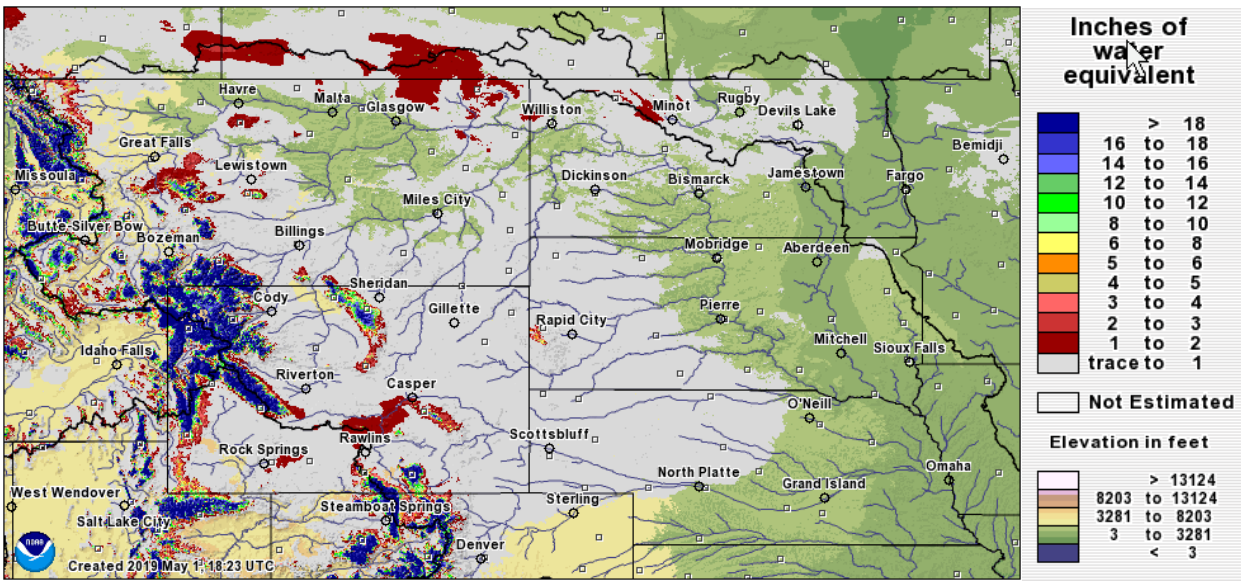


Figure 9. May 1, 2019 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reservoir reaches. It is typically NOT a factor influencing runoff at the beginning of a calendar year. **Figure 10** includes time series plots of the average mountain SWE beginning on October 1, 2018 based on the NRCS SNOTEL data for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of May 7, mountain SWE was about average in both reaches: 100% of average in the Fort Peck reach and 97% of average in the Garrison reach. In the Fort Peck reservoir reach, mountain SWE peaked at 105% of average on April 18. In the Garrison reservoir reach, mountain SWE peaked at 104% of average on April 17. The melt is slowly beginning to occur; however, the colder-than-normal temperature outlook may slow the snowmelt in the highest mountain elevations.

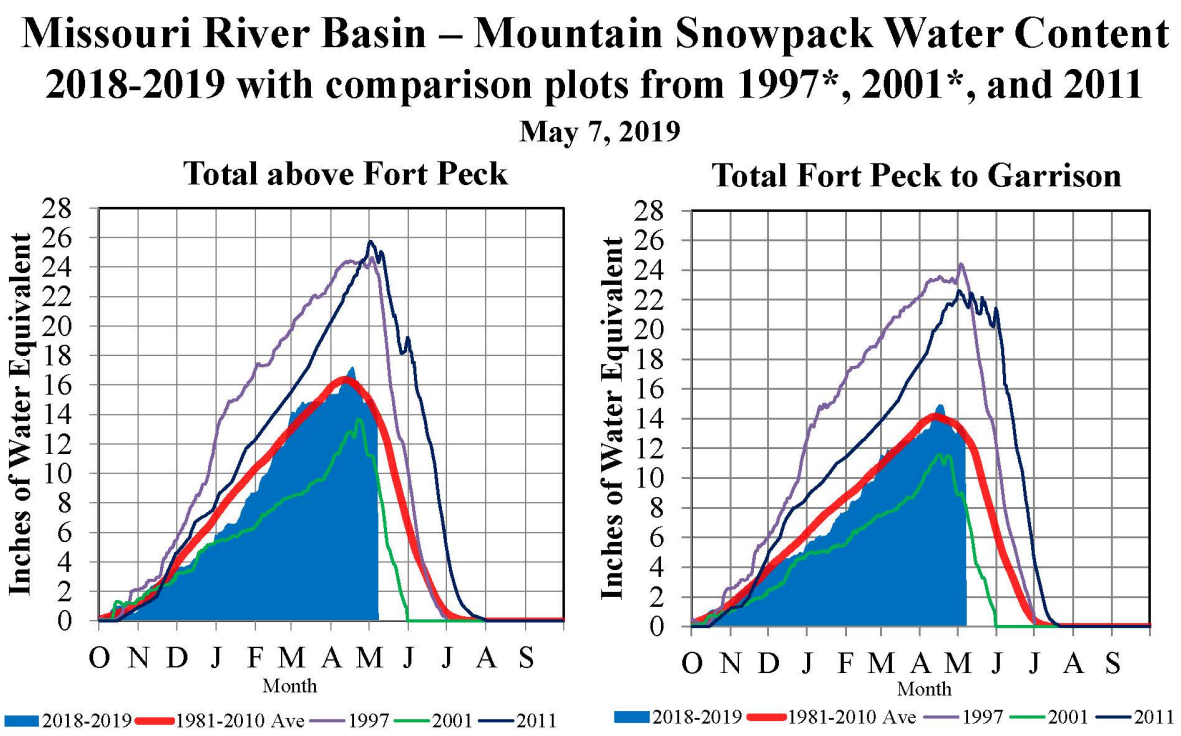


Figure 10. Mountain snowpack water content on May 7, 2019 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO Outlook indicates that weak El Niño conditions are present. Weak El Niño conditions are expected to continue through the Northern Hemisphere summer (~65% chance) and possibly fall summer (~50-55% chance).

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

With regard to future weather, the CPC precipitation outlook for May 12-16 (**Figure 11**) is indicating increased chances for below-normal precipitation over much of the Missouri Basin. There is an increased probability for above-normal precipitation in southern Wyoming and Colorado, and equal chances in southern Montana, northern Wyoming, western Nebraska and western Kansas.

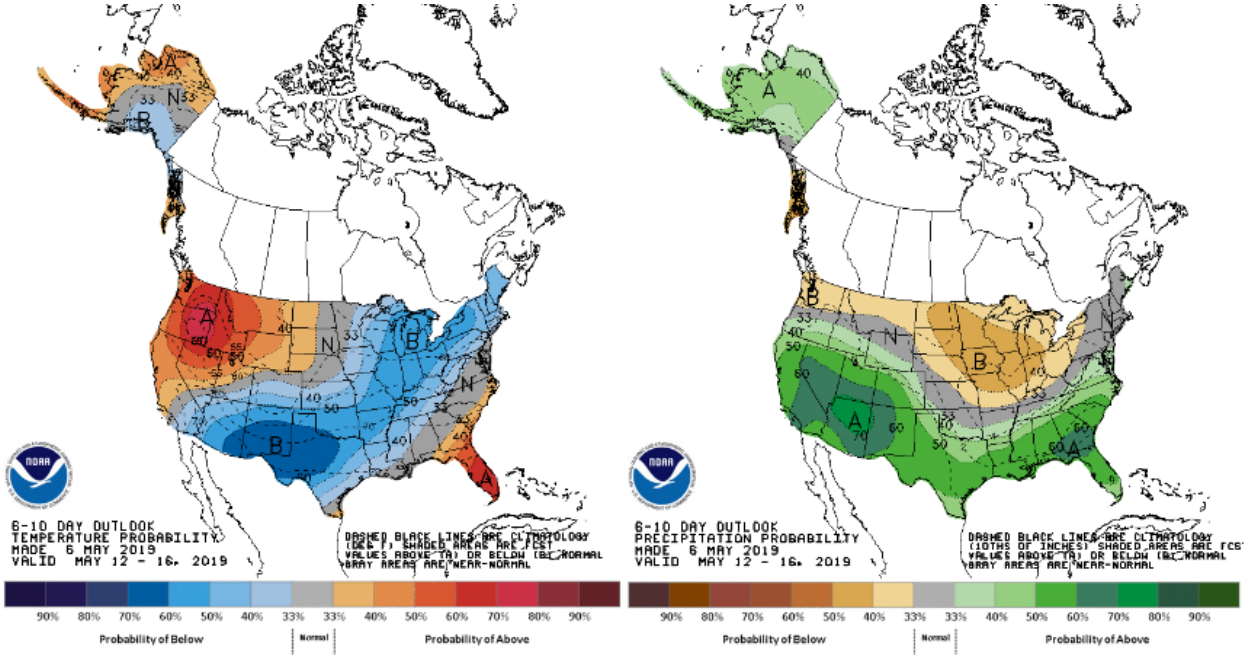


Figure 11. CPC 8-14 Day temperature and precipitation outlooks through May 16, 2019.

The May CPC outlooks in **Figure 12** indicates increased chances for precipitation from the central Rockies into the lower Basin, with a slight tilt toward above-normal precipitation in the upper Basin. The temperature outlook indicates increased chances for below-normal temperatures over most of the Missouri Basin.

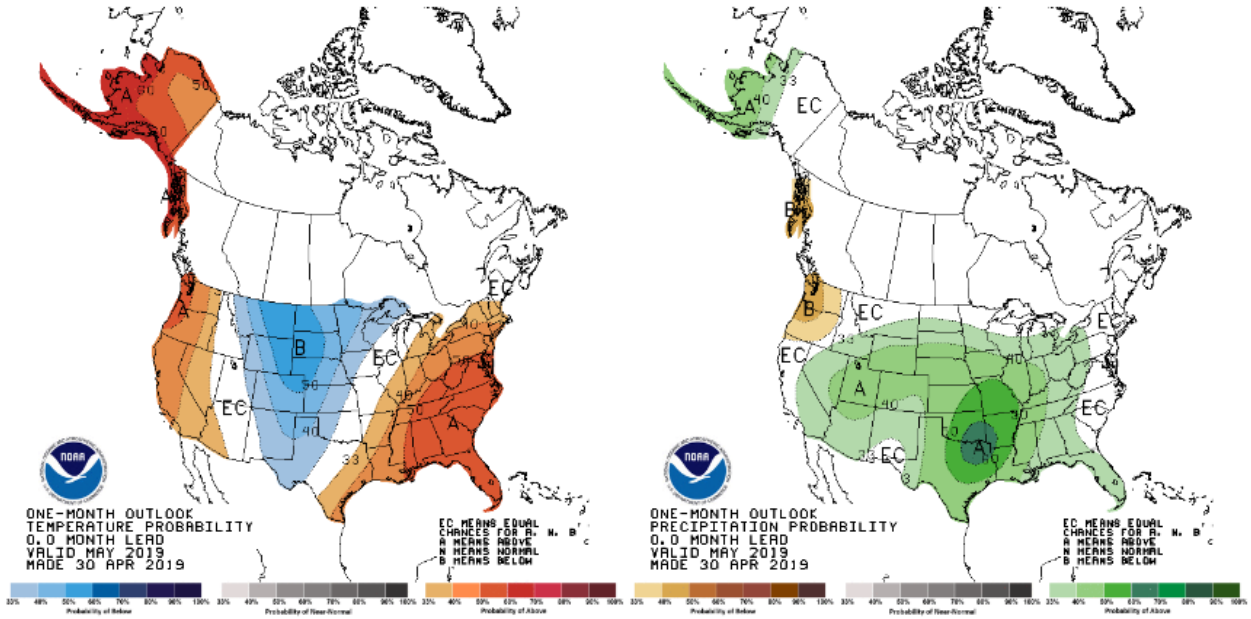


Figure 12. CPC May 2019 temperature and precipitation outlooks.

During the June-July-August 2019 period, the CPC outlooks in **Figure 13** are indicating increased chances for above-normal precipitation in all of the Missouri Basin, particularly in the western two-thirds of the Basin. With regard to temperature, CPC indicates increased chances for above-normal temperatures during the summer in the mountains, and equal chances in the central U.S.

During the September-October-November 2019 period, CPC outlooks in **Figure 14** indicate increased chances for above-normal temperatures over the entire Basin. The precipitation outlook indicates a slight increase in chances for above-normal precipitation over southern Wyoming, Colorado, and western Kansas.

The December 2019-January-February 2020 outlooks in **Figure 19** indicate increased chances for above-normal temperatures over the entire Basin. In regard to precipitation, there are equal chances throughout the Missouri Basin.

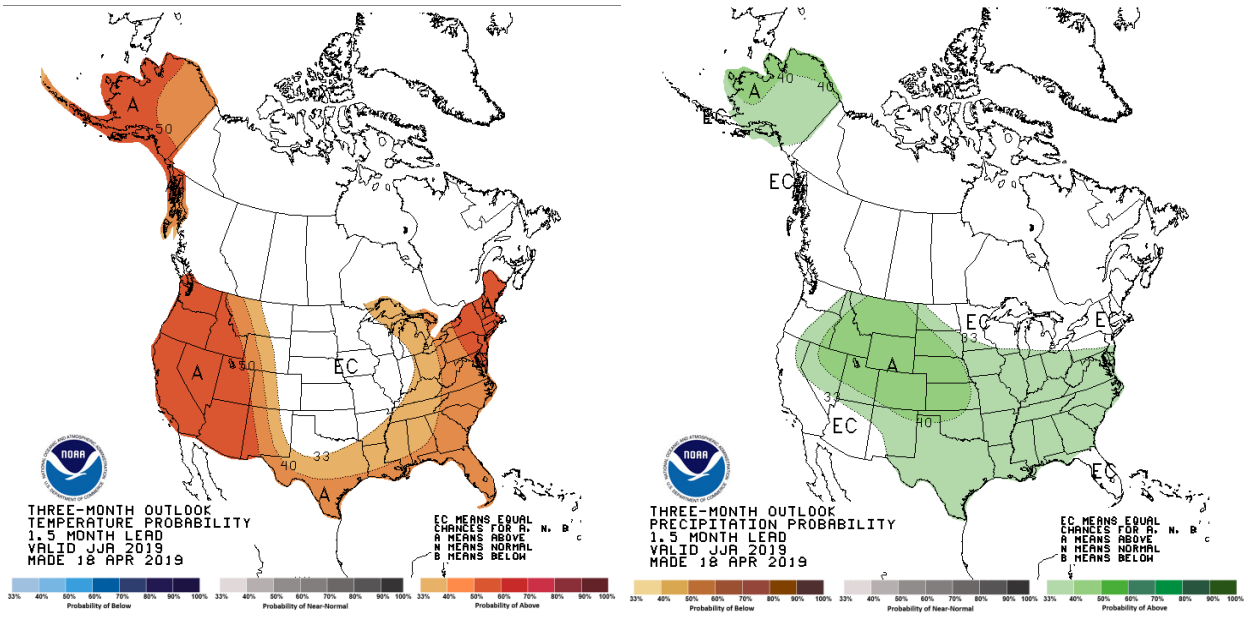


Figure 13. CPC June-July-August 2019 temperature and precipitation outlooks.

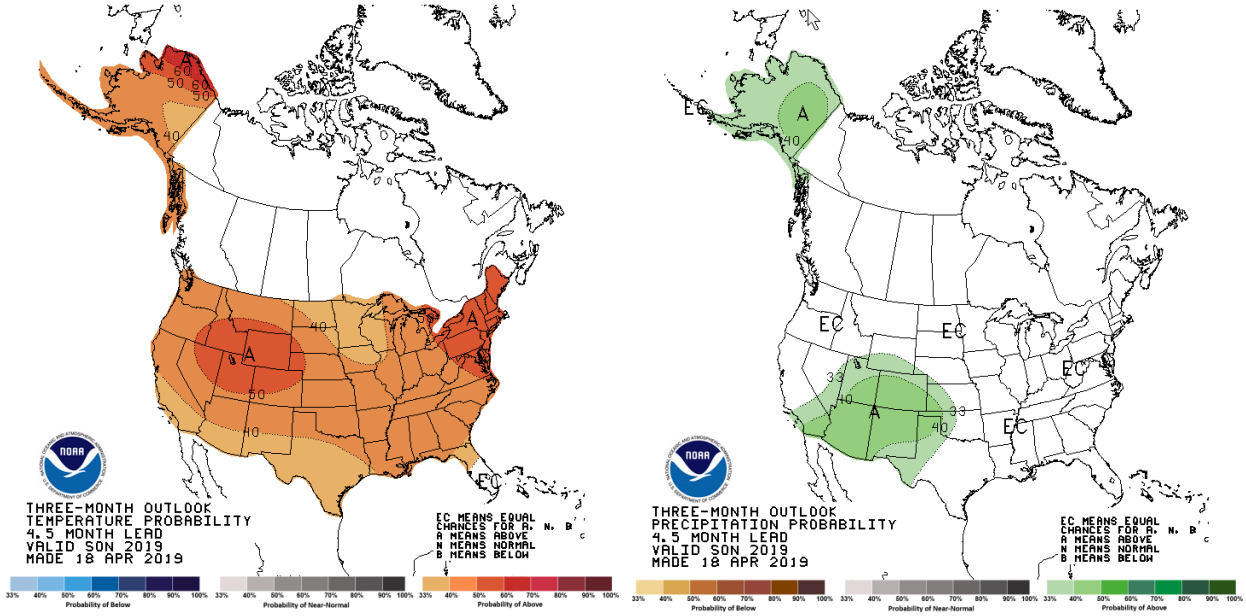


Figure 14. CPC September-October-November 2019 temperature and precipitation outlooks.

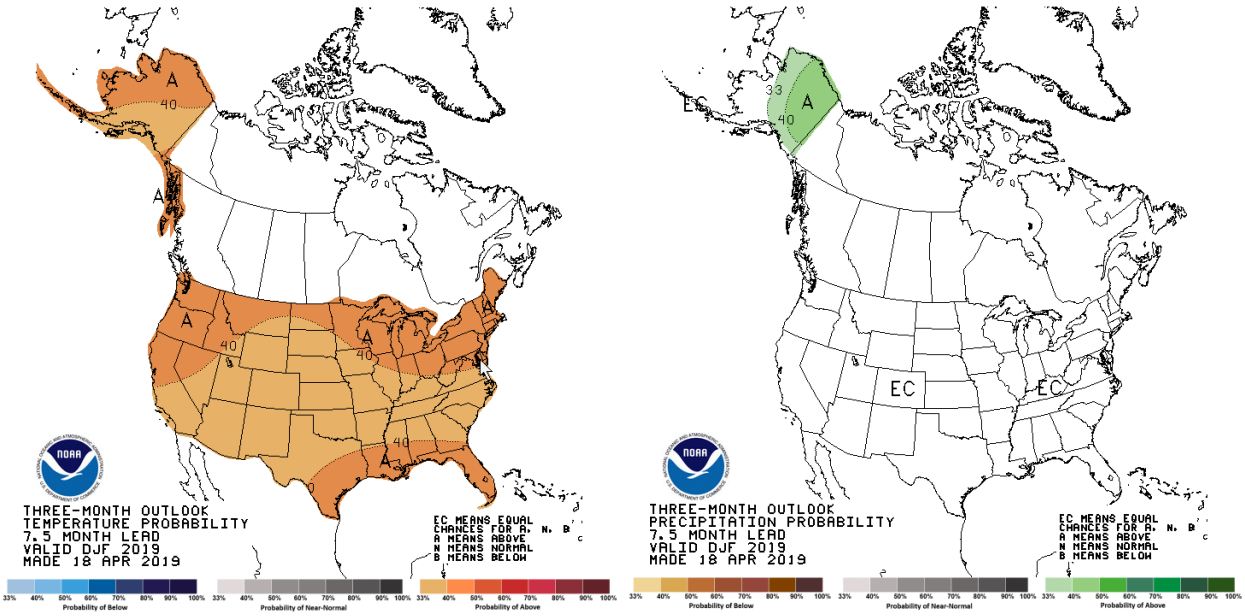
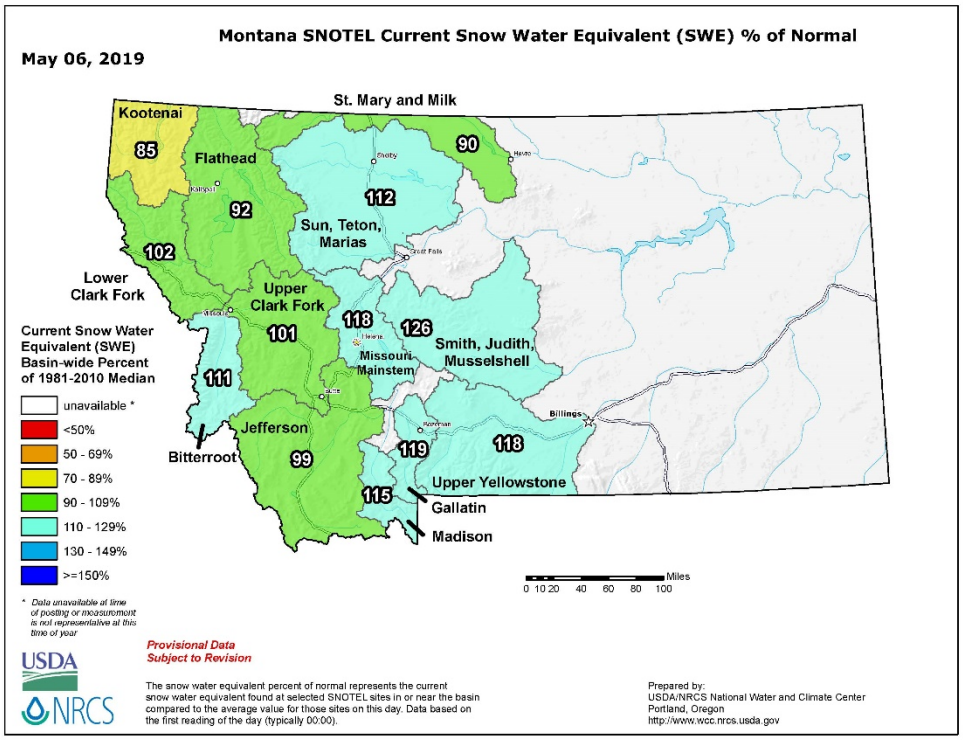


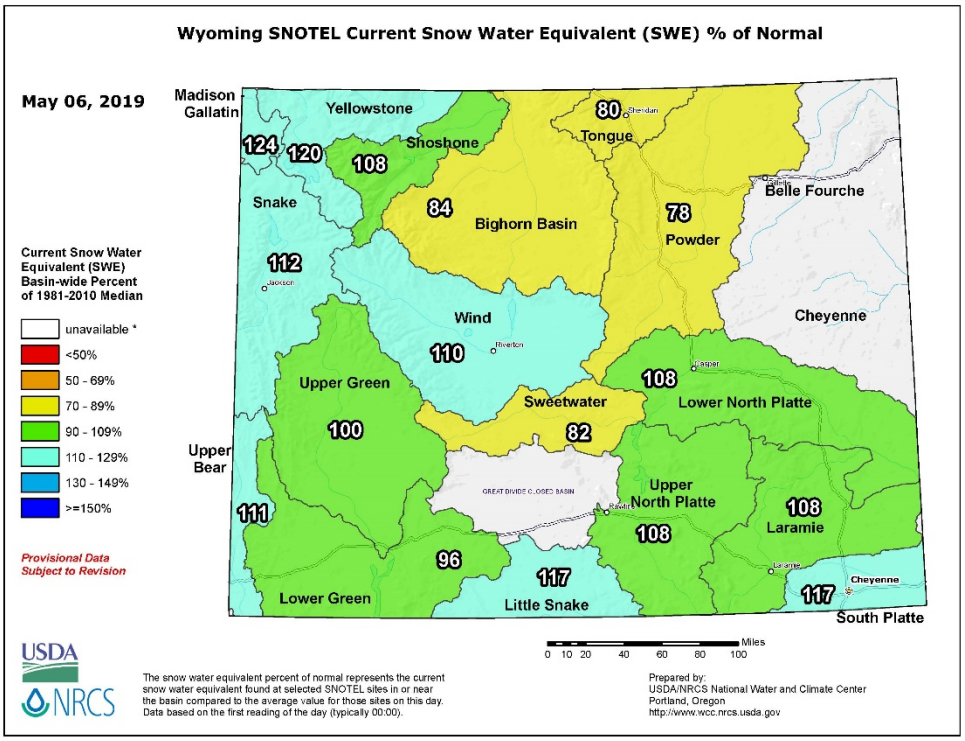
Figure 15. CPC December 2019-January-February 2020 temperature and precipitation outlooks.

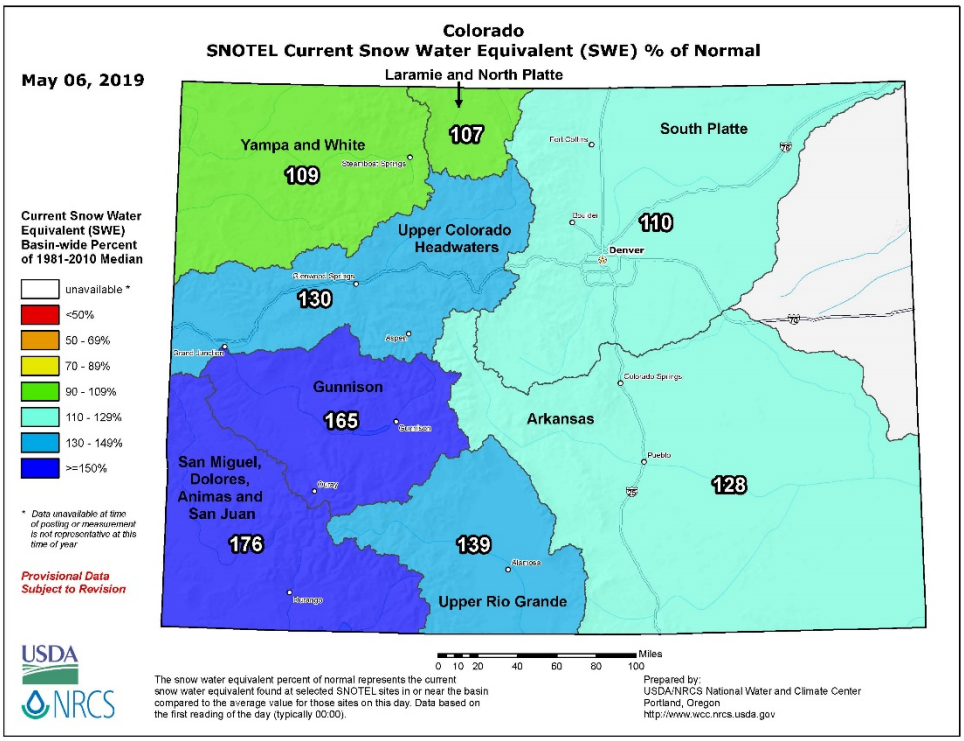
Summary

In summary, the updated 2019 calendar year runoff forecast is **43.2 MAF**, **170% of average**. Existing wet soil moisture conditions, high tributary baseflows, the mountain snowpack, and spring and summer precipitation are major factors in determining the May 1 forecast. The Sioux City reach, which includes the James and Big Sioux River basins, is not regulated by the Mainstem System. This reach has been a major contributor to upper Basin runoff above Sioux City, and we expect it to contribute greatly to upper Basin runoff during the spring and summer. During May, June and July, mountain snowpack in the Fort Peck and Garrison reaches is the primary source of upper Basin runoff.

Additional Figures






Colorado
SNOTEL Current Snow Water Equivalent (SWE) % of Normal
May 06, 2019
Laramie and North Platte
107
Yampa and White
109
South Platte
110
Upper Colorado Headwaters
130
Gunnison
165
Arkansas
128
San Miguel, Dolores, Animas and San Juan
176
139
Upper Rio Grande
Current Snow Water Equivalent (SWE) Basin-wide Percent of 1981-2010 Median
unavailable *
<50%
50 - 69%
70 - 89%
90 - 109%
110 - 129%
130 - 149%
>=150%
* Data unavailable at time of posting or measurement is not representative at this time of year
Provisional Data Subject to Revision
Miles
0 10 20 40 60 80 100
The snow water equivalent percent of normal represents the current snow water equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).
Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

USDA NRCS National Water & Climate Center
*** - DATA CURRENT AS OF: April 06, 2019 11:09:17 AM**
- Based on May 01, 2019 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow (2)	MAY-JUL	73	85	90	80	67	57	86
	MAY-SEP	87	86	106	95	80	68	101
St. Mary R at Intl Boundary (2)	MAY-JUL	330	83	425	370	295	240	400
	MAY-SEP	395	84	500	435	350	290	470
Lima Reservoir Inflow (2)	MAY-JUL	46	92	69	55	37	23	50
	MAY-SEP	51	91	77	61	41	25	56
Clark Canyon Reservoir Inflow (2)	MAY-JUL	41	64	86	59	23	-3.9	64
	MAY-SEP	57	69	112	79	35	2.1	83
Jefferson R nr Three Forks (2)	MAY-JUL	505	88	775	615	395	230	575
	MAY-SEP	540	85	860	670	415	225	635
Hebgen Lake Inflow (2)	MAY-JUL	330	108	395	355	305	265	305
	MAY-SEP	435	107	520	470	400	350	405
Ennis Lake Inflow (2)	MAY-JUL	565	107	675	610	520	455	530
	MAY-SEP	715	105	855	770	660	575	680
Missouri R at Toston (2)	MAY-JUL	1530	103	1980	1710	1350	1090	1480
	MAY-SEP	1790	102	2350	2010	1560	1230	1760
Smith R bl Eagle Ck (2)	MAY-JUL	103	116	149	122	84	57	89
	MAY-SEP	113	114	170	136	91	57	99
Gibson Reservoir Inflow (2)	MAY-JUL	280	79	345	305	255	215	355
	MAY-SEP	315	80	390	345	285	240	395
Marias R nr Shelby (2)	MAY-JUL	220	73	335	265	172	103	300
	MAY-SEP	230	73	355	280	179	104	315

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	MAY-JUL	60	105	67	63	57	53	57
	MAY-SEP	76	106	85	80	72	66	72
Wind R ab Bull Lake Ck	MAY-JUL	405	94	510	445	365	300	430
	MAY-SEP	435	94	550	480	390	320	465
Bull Lake Ck nr Lenore (2)	MAY-JUL	140	104	162	149	131	118	135
	MAY-SEP	171	103	197	181	160	145	166
Boysen Reservoir Inflow (2)	MAY-JUL	520	93	740	610	425	295	560
	MAY-SEP	565	92	800	660	470	330	615
Greybull R at Meeteetse	MAY-JUL	108	87	155	127	89	61	124
	MAY-SEP	149	88	205	171	126	93	170
Shell Ck nr Shell	MAY-JUL	39	75	53	45	33	25	52
	MAY-SEP	49	78	65	55	43	33	63
Bighorn R at Kane (2)	MAY-JUL	645	84	1010	790	495	280	770
	MAY-SEP	690	83	1070	845	535	305	830
NF Shoshone R at Wapiti	MAY-JUL	520	121	600	555	490	440	430
	MAY-SEP	585	121	675	620	545	490	485
SF Shoshone R nr Valley	MAY-JUL	215	108	255	230	200	178	200
	MAY-SEP	250	106	295	270	230	205	235
Buffalo Bill Reservoir Inflow	MAY-JUL	720	114	855	775	665	590	630
	MAY-SEP	805	115	950	860	745	660	700
Bighorn R nr St. Xavier (2)	MAY-JUL	1200	95	1660	1390	1020	745	1260
	MAY-SEP	1270	95	1760	1470	1070	775	1340
Little Bighorn R nr Hardin	MAY-JUL	37	44	80	54	19.6	1.00	85
	MAY-SEP	45	46	94	65	25	2.0	97
Tongue R nr Dayton (2)	MAY-JUL	44	55	69	54	34	19.2	80
	MAY-SEP	54	59	81	65	42	26	92
Tongue River Reservoir Inflow (2)	MAY-JUL	70	40	158	106	34	1.00	175
	MAY-SEP	86	43	180	124	49	1.00	198
NF Powder R nr Hazelton	MAY-JUL	5.9	71	9.1	7.2	4.7	2.8	8.3
	MAY-SEP	6.6	73	9.8	7.9	5.2	3.3	9.0
Powder R at Moorhead	MAY-JUL	93	62	215	143	43	1.00	151
	MAY-SEP	107	63	230	158	57	1.00	170
Powder R nr Locate	MAY-JUL	103	63	240	159	47	1.00	164
	MAY-SEP	117	63	260	175	58	1.00	185

PRELIMINARY RAPID VALLEY UNIT FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Deerfield Reservoir Inflow (2)	MAY-JUL	3.1	79	5.6	4.1	2.1	0.64	3.9
Pactola Reservoir Inflow (2)	MAY-JUL	12.8	73	24	17.4	8.2	1.41	17.5

PRELIMINARY PLATTE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
North Platte R nr Northgate (2)	MAY-JUL	230	123	325	270	192	137	187
	MAY-SEP	255	121	360	300	210	150	210
Encampment R nr Encampment (2)	MAY-JUL	153	130	195	170	137	112	118
	MAY-SEP	164	129	205	181	146	120	127
Rock Ck ab King Canyon Cnl nr Arlington	MAY-JUL	52	108	64	57	47	40	48
	MAY-SEP	55	110	67	60	50	42	50
Seminoe Reservoir Inflow (2)	MAY-JUL	755	123	990	850	660	515	615
	MAY-SEP	820	122	1070	925	720	570	670
Sweetwater R nr Alcova	MAY-JUL	36	78	59	45	27	12.6	46
	MAY-SEP	40	80	65	50	30	14.6	50
La Prele Ck nr Douglas	MAY-JUL	15.8	106	24	19.0	12.6	7.9	14.9
	MAY-SEP	16.2	109	24	19.4	13.0	8.3	14.8
North Platte R bl Glendo Reservoir (2)	MAY-JUL	780	116	1110	915	645	450	670
	MAY-SEP	820	117	1160	955	680	480	700
North Platte R bl Guernsey Reservoir (2)	MAY-JUL	785	117	1130	920	645	440	670
	MAY-SEP	825	118	1170	965	680	475	700
Laramie R and Pioneer Cnl nr Woods Lg (2)	MAY-JUL	114	106	152	130	98	76	108
	MAY-SEP	123	103	165	140	106	81	119
Little Laramie R nr Filmore	MAY-JUL	52	108	67	58	46	37	48
	MAY-SEP	55	106	72	62	48	38	52

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
June 2019 Calendar Year Runoff Forecast
June 4, 2019

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

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

May runoff for the upper Basin above Sioux City was 8.9 MAF, 267% of average, and the second highest May runoff summation in the 121 years of record-keeping, exceeded only in 2011 (9.2 MAF). May runoff in the Gavins Point to Sioux City reach (2.1 MAF), the Fort Randall to Gavins Point reach (652 kAF), and the Garrison to Oahe reach (1.6 MAF) were the highest in 121 years of record-keeping. The May runoff in the Oahe to Fort Randall reach (1.4 MAF) was second highest (record is 1.7 MAF in 1942). January through May runoff was 29.6 MAF, which is more than 4 MAF higher than the long-term annual average of 25.3 MAF. The March-April-May runoff of 27.6 MAF exceeded the previous record (23.3 MAF in 2011) for these three months.

2019 Calendar Year Forecast Synopsis

The 2019 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA is **50.0 MAF, 197% of average**. The forecast increased almost 7 MAF from the May 1 forecast due to: the observed much-above-average May runoff, the fully saturated soil conditions throughout much of the upper basin, the long-term precipitation and temperature outlooks, and the current mountain snowpack conditions. The 2019 calendar year runoff forecast above Gavins Point

Dam, which does not include runoff from the James, Vermillion and Big Sioux rivers, is **39.5 MAF, 171% of average**. Soil conditions continue to be wet (and in some areas, very wet) in the Missouri Basin. The plains snow has all melted in the upper Basin. Recent precipitation outlooks have indicated stronger likelihoods for above-normal precipitation over the next several months.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 7 months, expected inflow could range from the **57.9 MAF** upper basic forecast to the **42.8 MAF** lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that seven months are being forecast for this June 1 forecast (5 months observed/7 months forecast), the range of possible wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is very large, and is attributed to all 6 reaches for the entire year. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for May 28, 2019 is shown in **Figure 1**. The drought monitor is available at http://droughtmonitor.unl.edu/. The Drought Monitor shows some isolated areas of Abnormal Dryness (D0) present in Wyoming.

The Seasonal Drought Outlook in **Figure 2**, which extends through the end of July, indicates there is not likely to be any classification change across most of the Missouri Basin. Some drought improvement is likely to occur over the Bighorn Range in Wyoming as the mountain snow melts during the spring and summer.

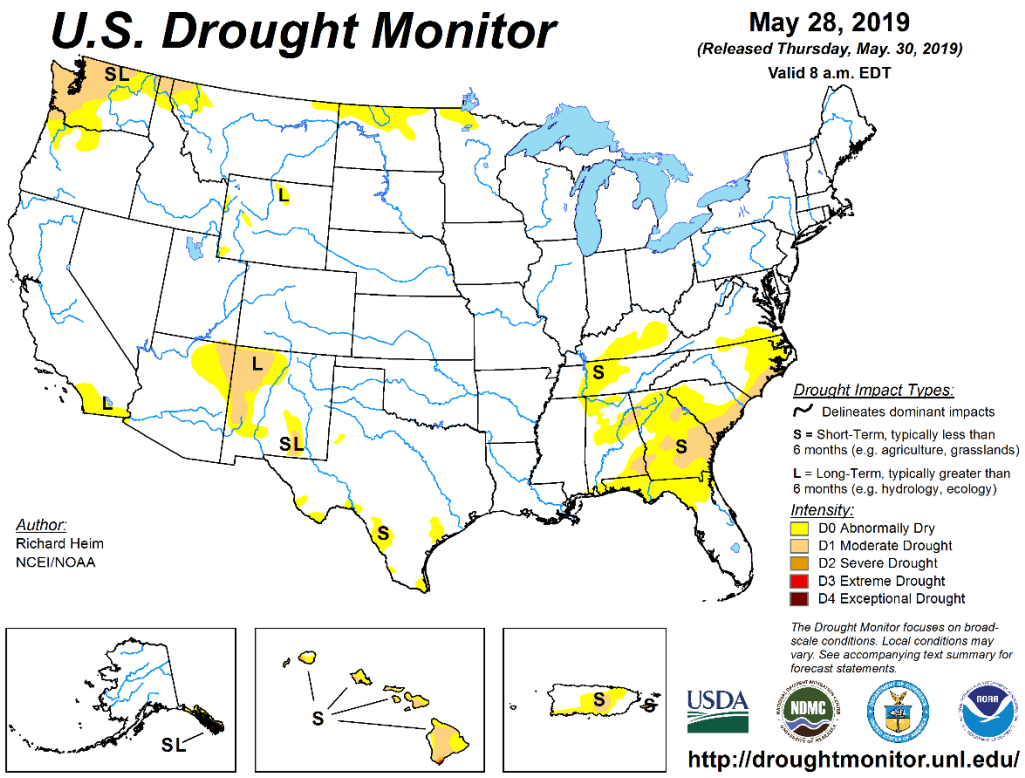


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for May 28, 2019.

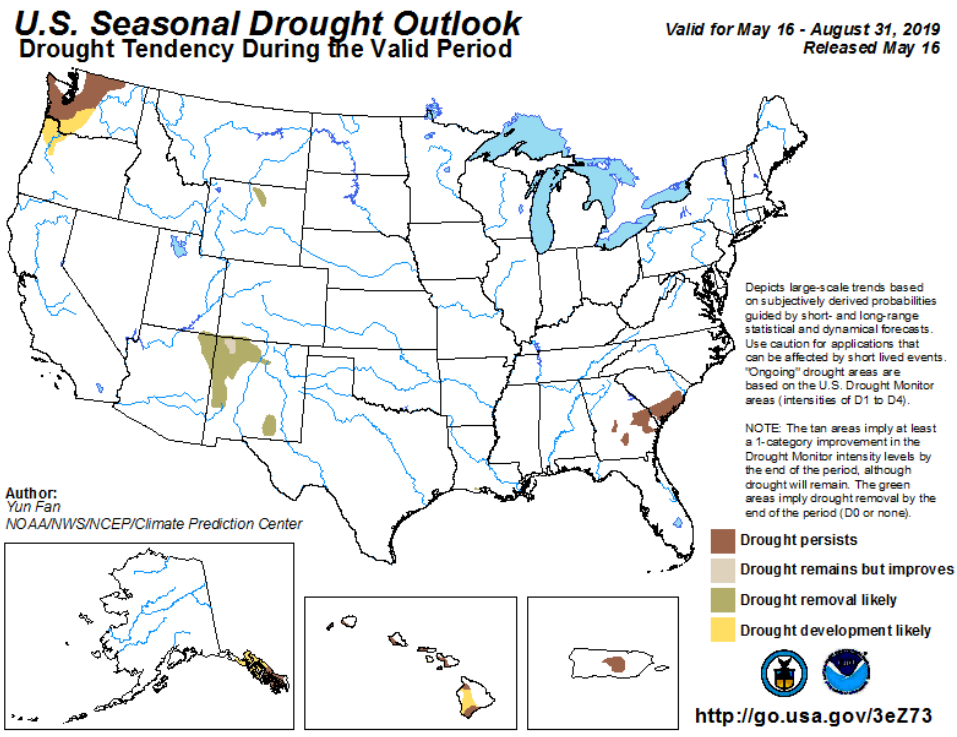


Figure 2. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. Precipitation as a percent of normal in May is shown in the left image of **Figure 3**, and March-April-May precipitation as a percent of normal is shown in the right image of **Figure 3**. May precipitation was two to six times above normal over major portions of the basin, particularly in western South Dakota, central Wyoming, central Nebraska, almost all of Kansas and western Missouri. For the last 3 months, those same areas were two to three times above normal. **Figures 4** and **5** note the statewide ranks for May and for the March-May period, respectively. As shown on **Figure 4**, May precipitation was the highest in 125 years of record in Nebraska, Kansas and Missouri. As shown in **Figure 5**, the March-May spring precipitation was the highest on record for Kansas.

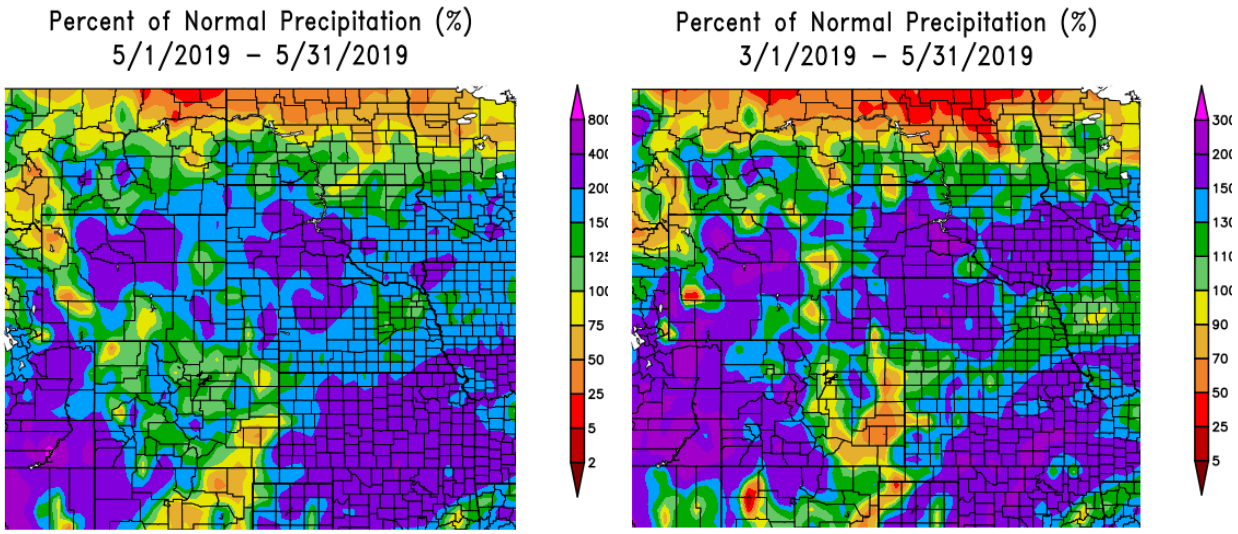


Figure 3. May 2019 and March-April-May 2019 Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

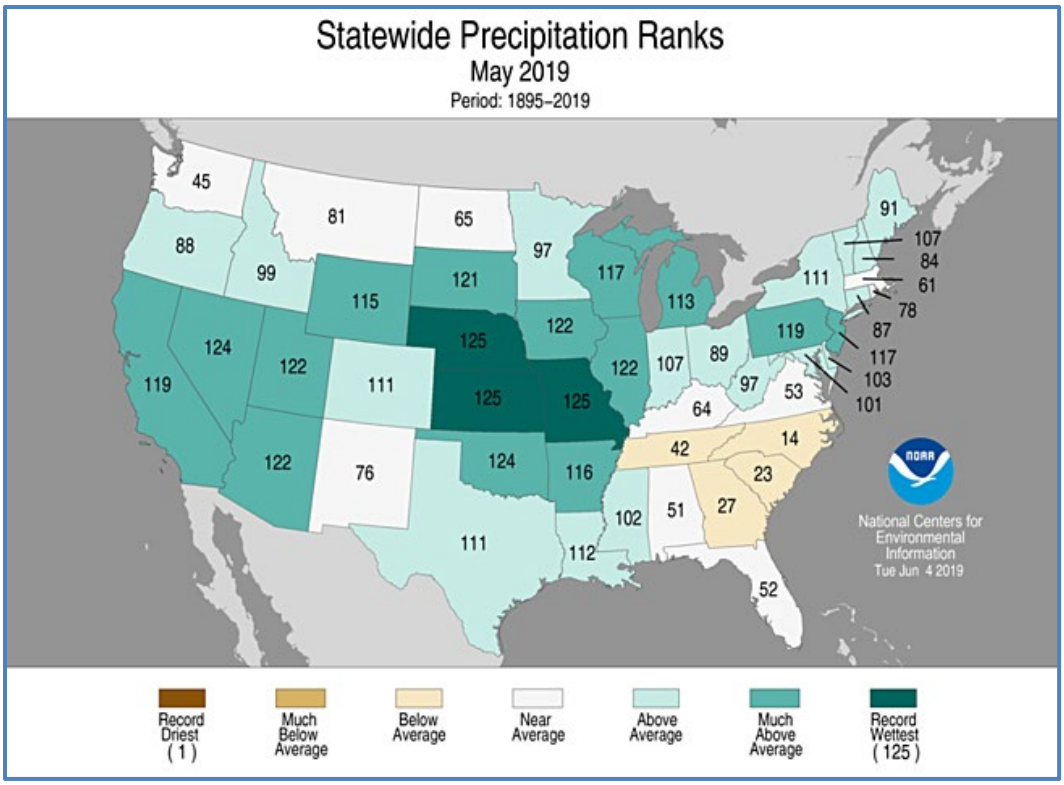


Figure 4. May 2019 Precipitation Statewide Ranking. Source: NOAA National Centers for Environmental Information, https://www.ncdc.noaa.gov/temp-and-precip/us-maps/1/201905?products[]=statewidepcpnrank#us-maps-select

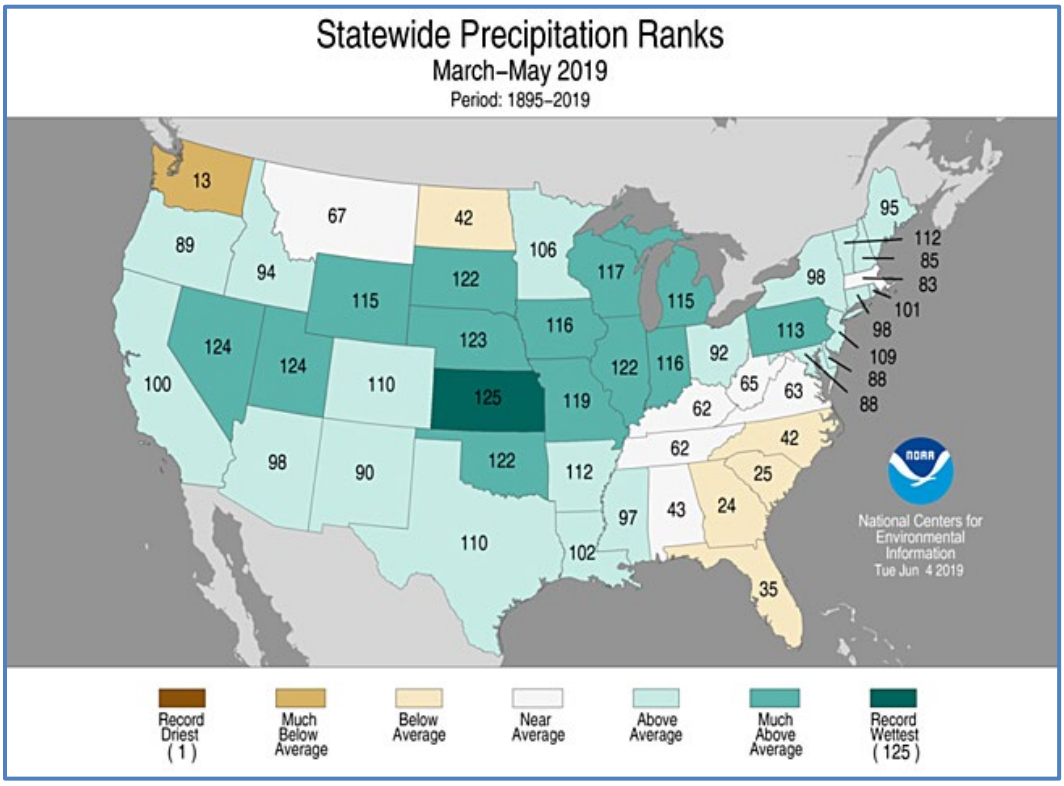


Figure 5. March-May 2019 Precipitation Statewide Ranking. Source: NOAA National Centers for Environmental Information, https://www.ncdc.noaa.gov/temp-and-precip/us-maps/3/201905?products[]=statewidepcpnrank#us-maps-select

Temperature departures for May are shown in degrees Fahrenheit (deg F) in the right image of **Figure 6**. Departures ranged from normal to below normal throughout the upper Basin. Temperatures were about 6 to 10 deg F below normal in western South Dakota, western Nebraska and central Wyoming. Temperatures in the lower Basin were 2 to 6 deg F below normal. March-April-May temperature departures, shown in the right image of **Figure 6,** show the colder-than-normal temperature pattern that impacted much of the Missouri Basin in February and March**.** In most of the upper Basin, departures ranged from 4 to over 8 degrees below normal. These cold temperatures directly influenced the continued formation of mountain and plains snowpack in March and intermittently during April.

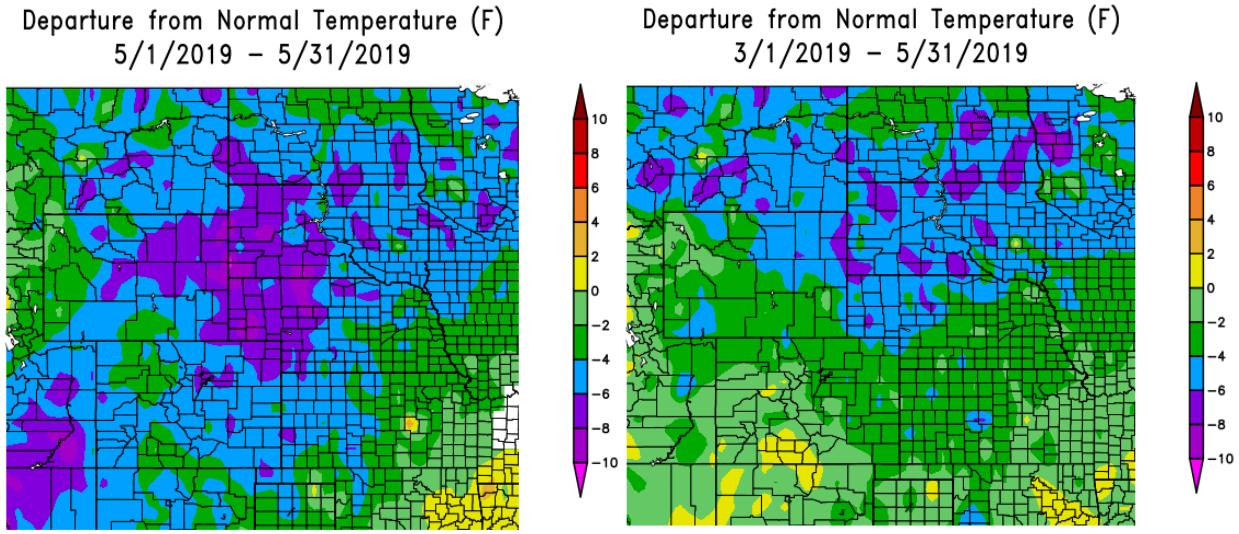


Figure 6. May 2019 and March-April-May 2019 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 7 shows the May 30, 2019 NOAA NLDAS ensemble soil moisture anomaly and soil moisture percentile. **Figure 8** shows the June 3, 2019 NOAA CPC soil moisture anomaly and soil moisture percentile. Based the NLDAS and CPC maps, and aside from Colorado and North Dakota, soils are very wet in central Montana, northeastern Wyoming, and a majority of all other states in the basin -- South Dakota, Nebraska, Iowa, Kansas and Missouri.

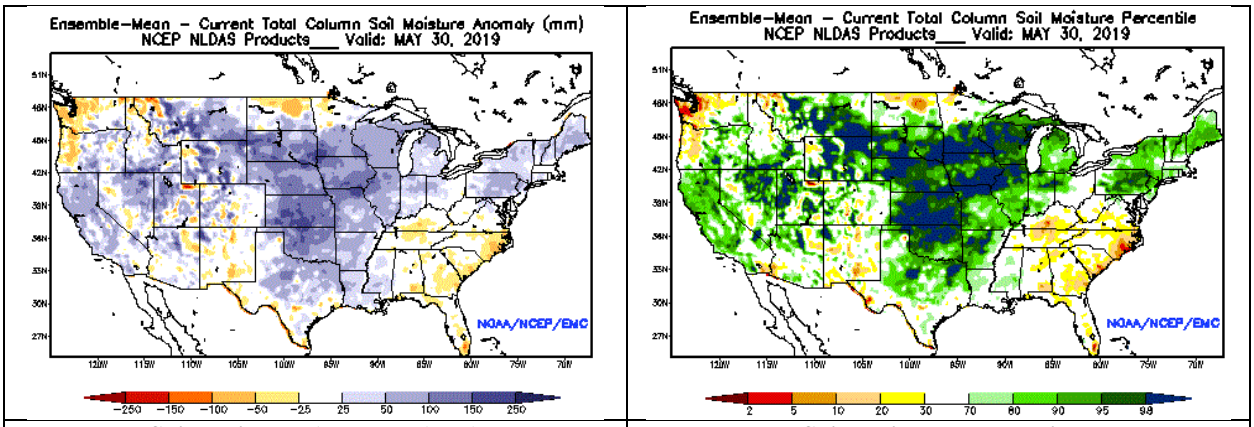


Figure 7. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

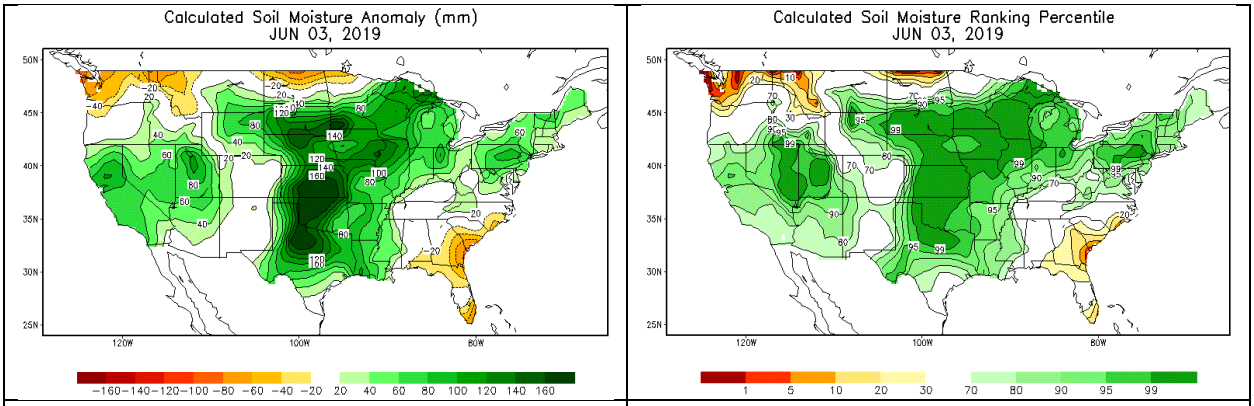


Figure 8. NOAA CPC Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA CPC. https://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reservoir reaches. It is typically NOT a factor influencing runoff at the beginning of a calendar year. **Figure 9** includes time series plots of the average mountain SWE beginning on October 1, 2018 based on the NRCS SNOTEL data for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of June 4, mountain SWE was above average in both reaches: 105% of the June 4 average in the Fort Peck reach and 148% of the June 4 average in the Garrison reach. In the Fort Peck reservoir reach, mountain SWE peaked at 105% of average on April 18 and 33% of the snow still remains to be melted. In the Garrison reservoir reach, mountain SWE peaked at 104% of average on April 17 and 56% of the snow still remains to be melted. The melt is occurring a bit slower than average due to the colder-than-normal temperatures. In addition, a boost in

mountain snowpack in late May appears to have slowed the snowmelt in the highest mountain elevations.

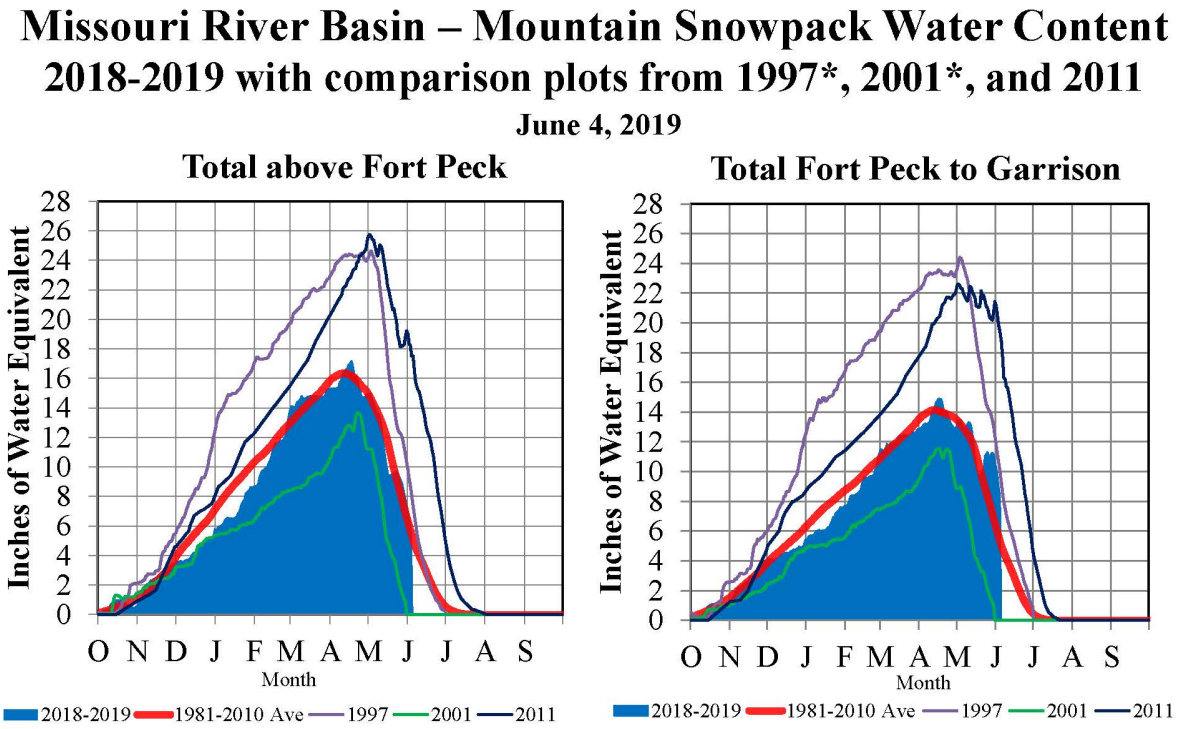


Figure 9. Mountain snowpack water content on June 4, 2019 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The CPC's June 3, 2019 ENSO Outlook indicates that El Niño conditions are present. Per the CPC, El Niño conditions are likely to continue through the Northern Hemisphere through the summer of 2019 (70% chance) and fall (55-60% chance).

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

With regard to future weather, the CPC temperature outlook for June 11-17 (**Figure 10, left**) is indicating increased chances for below-normal temperatures over much of the Missouri Basin. Regarding precipitation (**Figure 10, right**), the CPC is indicating an increased probability for below-normal precipitation in the far northern portions of the basin, normal precipitation in a small band across South Dakota and above-normal precipitation for the lower basin.

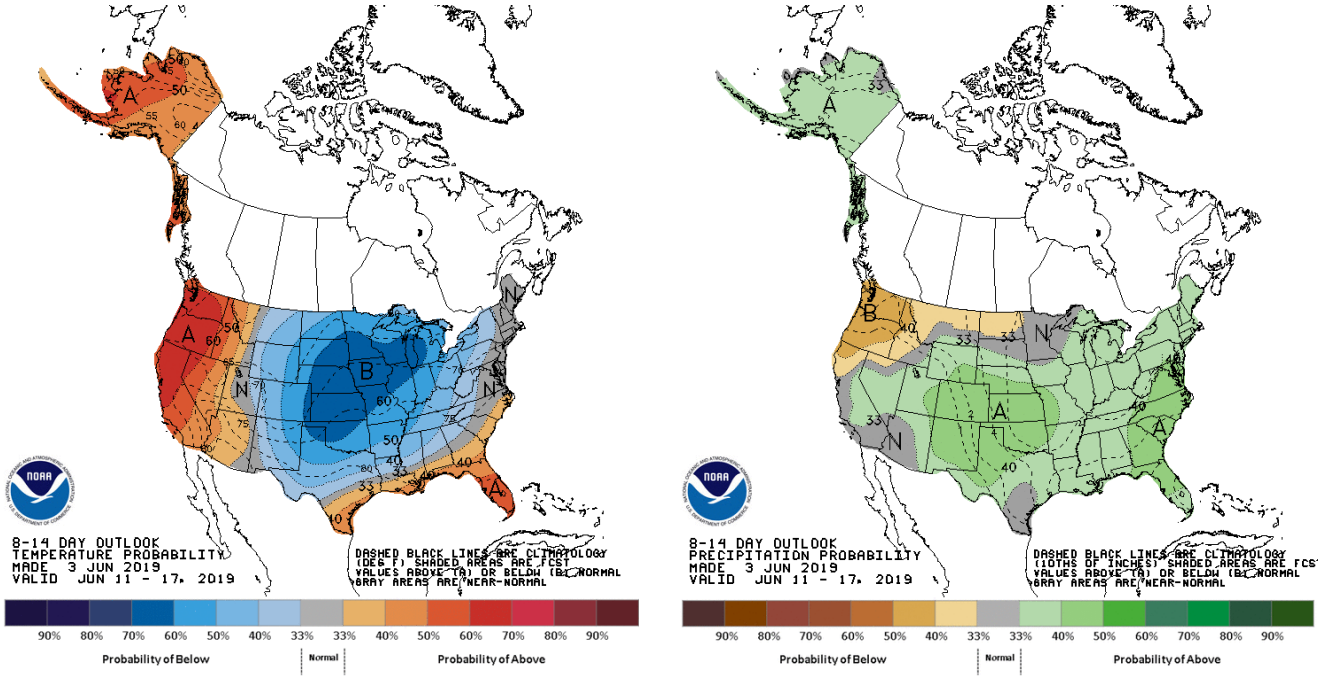


Figure 10. CPC 8-14 Day temperature and precipitation outlooks for June 11-17, 2019.

The June CPC outlooks in **Figure 11** indicate increased chances for above-normal precipitation in the lower Basin and equal chances for precipitation in the upper basin. The temperature outlook indicates a mixture – increased chances for above-normal temperatures in the far north, equal chances for most of the rest of the basin, and increased chances for below-normal temperatures in Kansas.

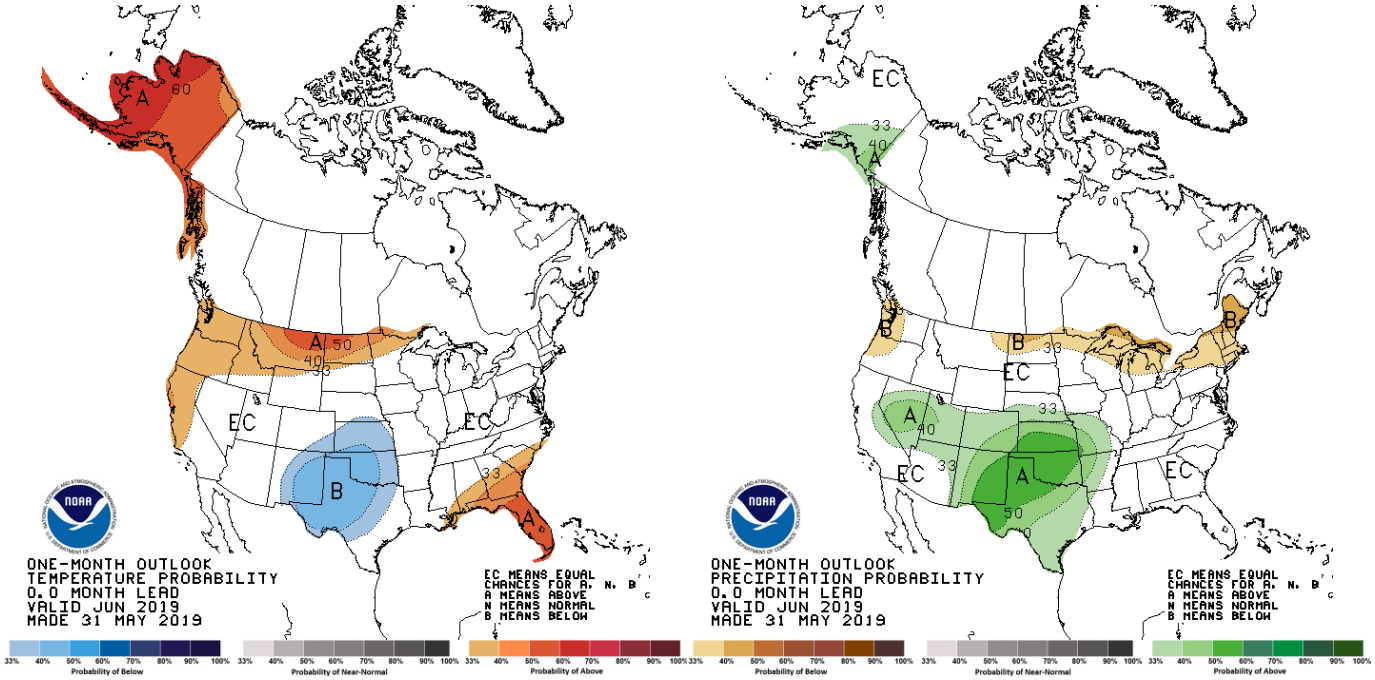


Figure 11. CPC June 2019 temperature and precipitation outlooks.

During the July-August-September 2019 period, the CPC outlooks in **Figure 12** are indicating increased chances for above-normal precipitation in most of the Missouri Basin. With regard to temperature, the CPC indicates equal chances for a majority of the basin with increased chances for below-normal temperatures in southeastern South Dakota, eastern Nebraska, Iowa, northwestern Missouri and most of Kansas.

During the October-November-December 2019 period, CPC outlooks in **Figure 13** indicate equal chances for precipitation over most of the entire Basin. The temperature outlook indicates increased chances for above-normal temperatures over the entire Basin.

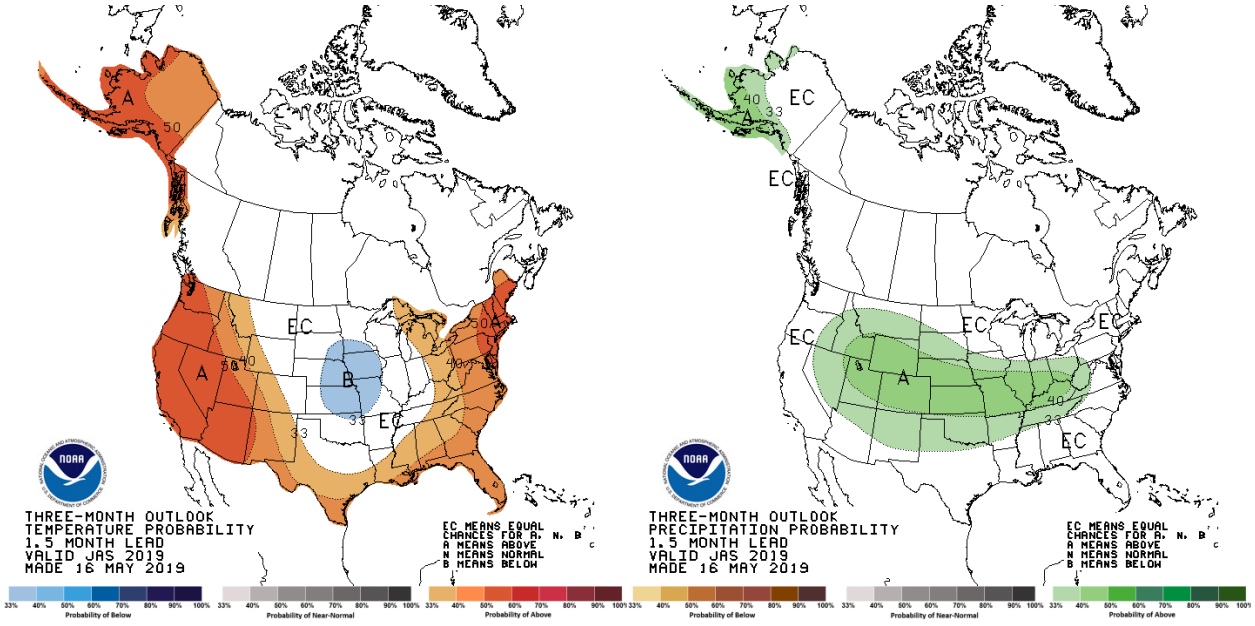


Figure 12. CPC July-August-September 2019 temperature and precipitation outlooks.

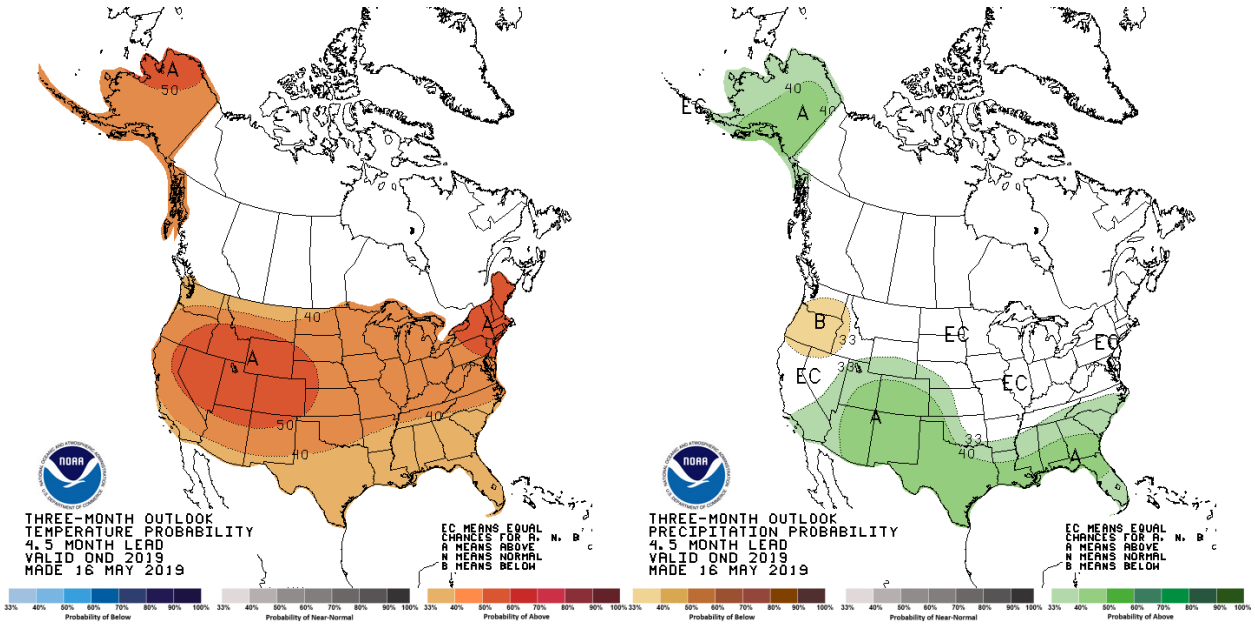
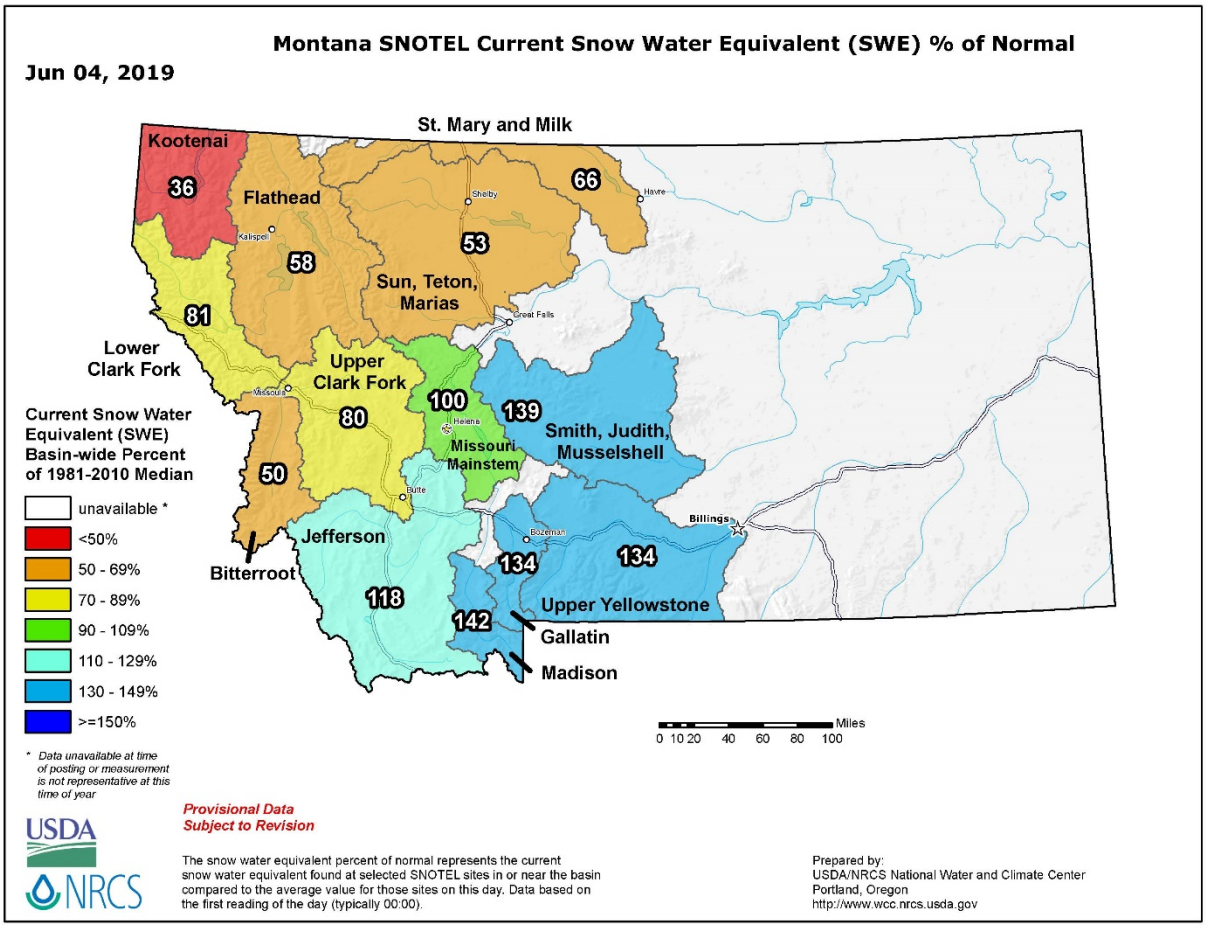


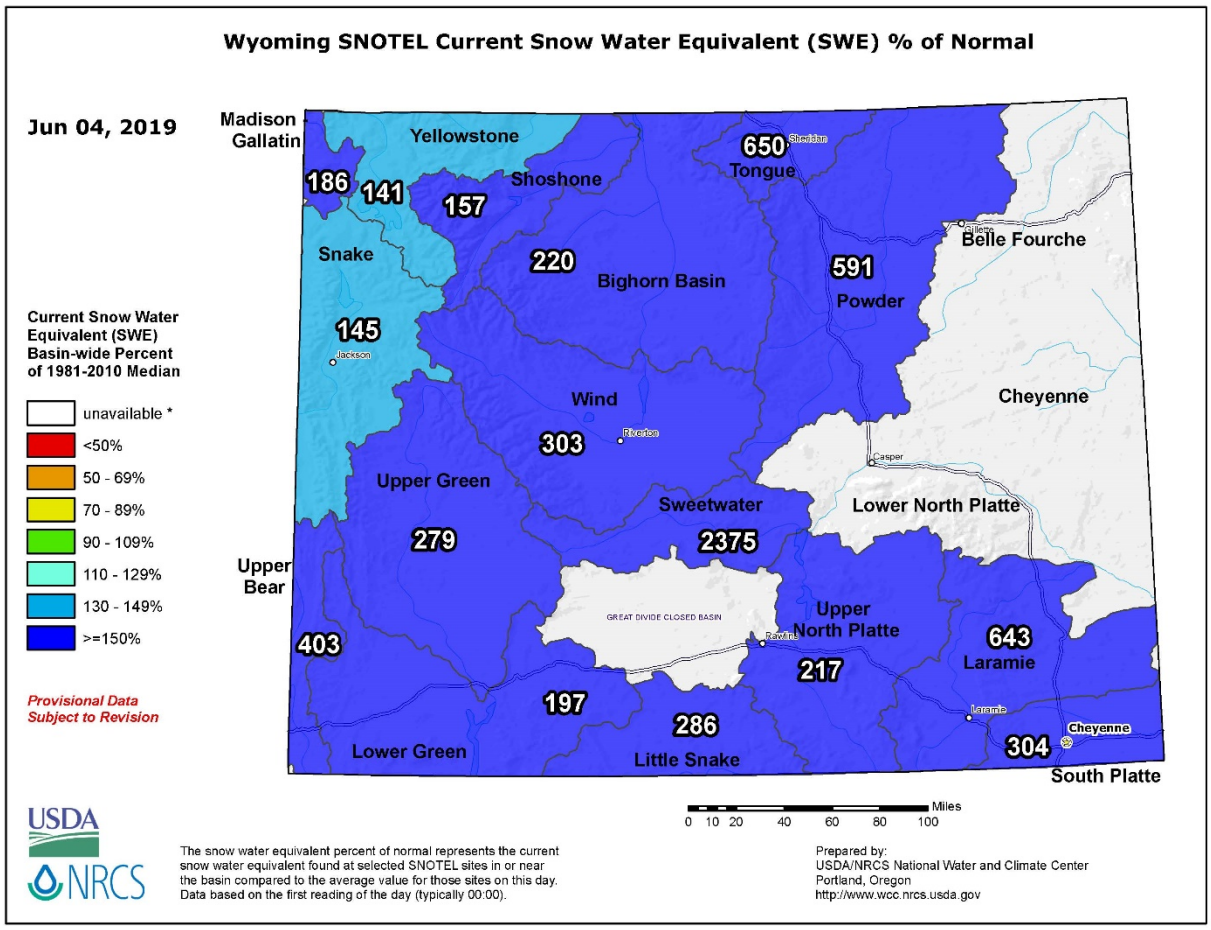
Figure 13. CPC October-November-December 2019 temperature and precipitation outlooks.

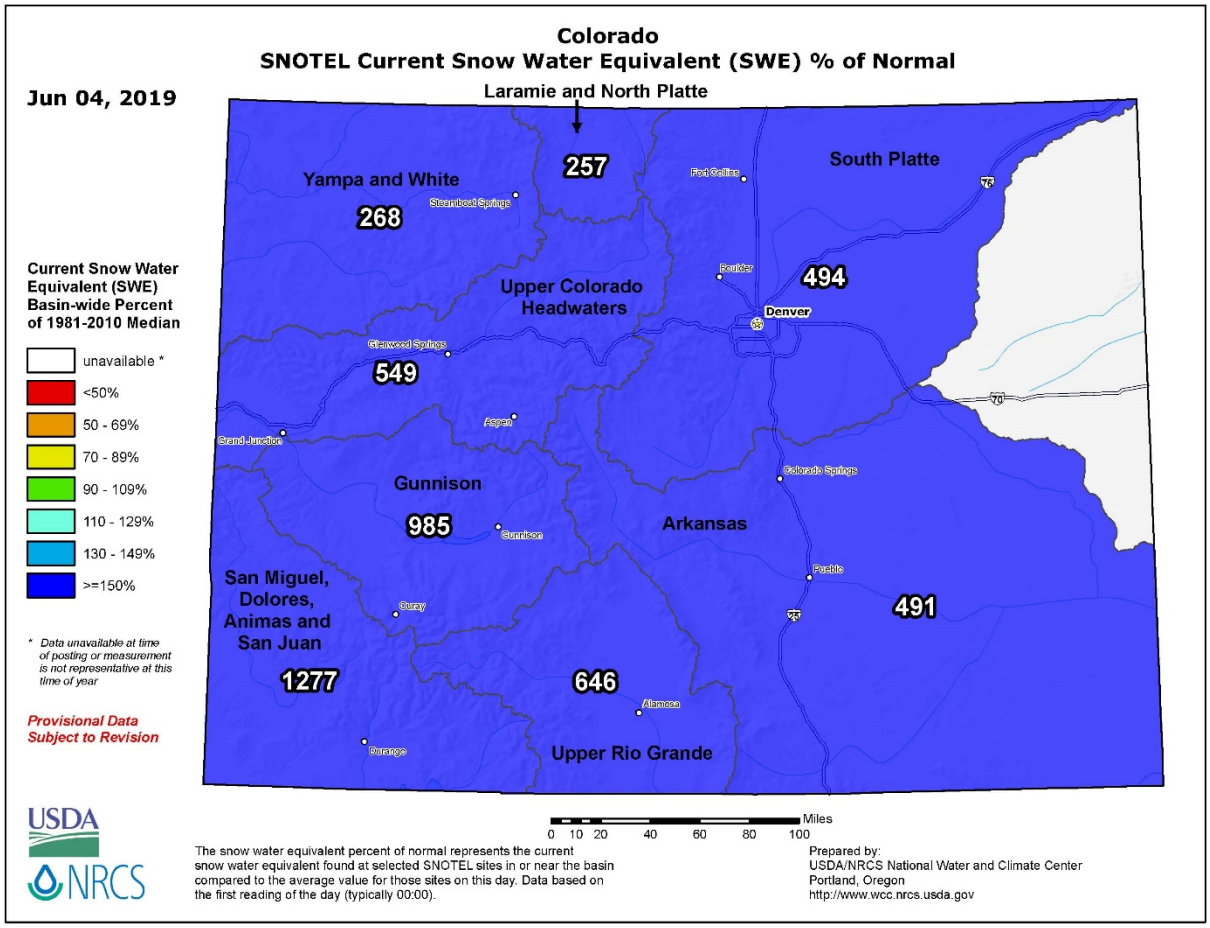
Summary

In summary, the updated 2019 calendar year runoff forecast is **50.0 MAF**, **197% of average**. Existing wet soil moisture conditions, high tributary baseflows, the remaining mountain snowpack, and forecasted summer and fall precipitation are major factors in determining the June 1 forecast. The Sioux City reach, which includes the James and Big Sioux River basins, is not regulated by the Mainstem System. This reach has been a major contributor to upper Basin runoff above Sioux City, and we expect it to contribute greatly to upper Basin runoff during the summer and fall. During May, June and July, mountain snowpack in the Fort Peck and Garrison reaches is the primary source of upper Basin runoff.

Additional Figures




Wyoming SNOTEL Current Snow Water Equivalent (SWE) % of Normal
Jun 04, 2019
Current Snow Water Equivalent (SWE) Basin-wide Percent of 1981-2010 Median
unavailable *
<50%
50 - 69%
70 - 89%
90 - 109%
110 - 129%
130 - 149%
>=150%
Provisional Data Subject to Revision
Madison Gallatin
Yellowstone
Shoshone
Snake
Bighorn Basin
Tongue
Belle Fourche
Powder
Cheyenne
Wind
Upper Green
Sweetwater
Lower North Platte
Upper Bear
GREAT DIVIDE CLOSED BASIN
Upper North Platte
Laramie
Lower Green
Little Snake
South Platte
186
141
157
220
650
591
145
303
279
2375
403
217
643
197
286
304
Jackson
Riverton
Casper
Rawlins
Laramie
Cheyenne
Sheridan
Miles
0 10 20 40 60 80 100
USDA NRCS
The snow water equivalent percent of normal represents the current snow water equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).
Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov


Colorado
SNOTEL Current Snow Water Equivalent (SWE) % of Normal
Jun 04, 2019
Laramie and North Platte
257
South Platte
Yampa and White
268
Steamboat Springs
Fort Collins
Upper Colorado Headwaters
494
Parker
Denver
Glenwood Springs
549
Aspen
Grand Junction
Gunnison
985
Arkansas
Colorado Springs
Pueblo
491
San Miguel, Dolores, Animas and San Juan
1277
646
Alamosa
Durango
Upper Rio Grande
Current Snow Water Equivalent (SWE) Basin-wide Percent of 1981-2010 Median
unavailable *
<50%
50 - 69%
70 - 89%
90 - 109%
110 - 129%
130 - 149%
>=150%
* Data unavailable at time of posting or measurement is not representative at this time of year
Provisional Data Subject to Revision
0 10 20 40 60 80 100
Miles
The snow water equivalent percent of normal represents the current snow water equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).
Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

Upper Missouri River Basin
July 2019 Calendar Year Runoff Forecast
July 5, 2019

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

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

June upper Basin runoff was 8.7 MAF, about 160% of the monthly average. Runoff was above average in all reservoir reaches. Runoff in the Garrison reach was 3.9 MAF (144%) due to above-normal precipitation that occurred near the end of May, some of which accumulated as snow in the mountains. In addition, the Milk River Basin and the Missouri River tributaries from Fort Peck to Garrison, excluding the Yellowstone River, received above-normal precipitation in June. Although precipitation in the Oahe to Gavins Point reaches was predominantly below normal, June runoff volumes continued to be above average. The Gavins Point reach received about three times the average June runoff, following a similar departure in May. In the reach from Gavins Point Dam to Sioux City, IA, runoff was more than four times the average June runoff due to high streamflows on the Big Sioux, James, and Vermillion rivers caused by heavy precipitation in May. Overall, the upper Basin has received 38.3 MAF of runoff as of July 1, which is 232% of the normal July 1 volume. Compared to the long-term annual runoff record, 2019 runoff on July 1 would rank as the 6th highest annual runoff volume with six months of the year remaining.

2019 Calendar Year Forecast Synopsis

The 2019 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA is **49.9 MAF, 197% of average**. The 2019 calendar year runoff forecast above Gavins Point Dam, which does not include runoff from the James, Vermillion and Big Sioux rivers, is **39.3 MAF, 170% of average**. If realized, this would be the second highest runoff in 121 years of record-keeping, exceeding 1997's 49.0 MAF. The record is 61.0 MAF, set in 2011.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 6 months, expected inflow could range from the **53.8 MAF** upper basic forecast to the **46.3 MAF** lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that six months are being forecast for this July 1 forecast (6 months observed/6 months forecast), the range of possible wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is attributed to all 6 reaches for the entire year, particularly as it relates to summer and fall precipitation. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for July 2, 2019 is shown in **Figure 1**. The drought monitor is available at http://droughtmonitor.unl.edu/. The Drought Monitor shows some isolated areas of Abnormal Dryness (D0) near Lake Sakakawea in North Dakota, and some Moderate Drought (D1) north of the lake; however, more the 98% of the Missouri Basin is unaffected by drought or abnormally dry conditions.

The Seasonal Drought Outlook in **Figure 2**, which extends through the end of September, indicates the abnormally dry conditions could persist in northeastern Montana and northern North Dakota; however, no drought conditions are expected to develop by the end of September.

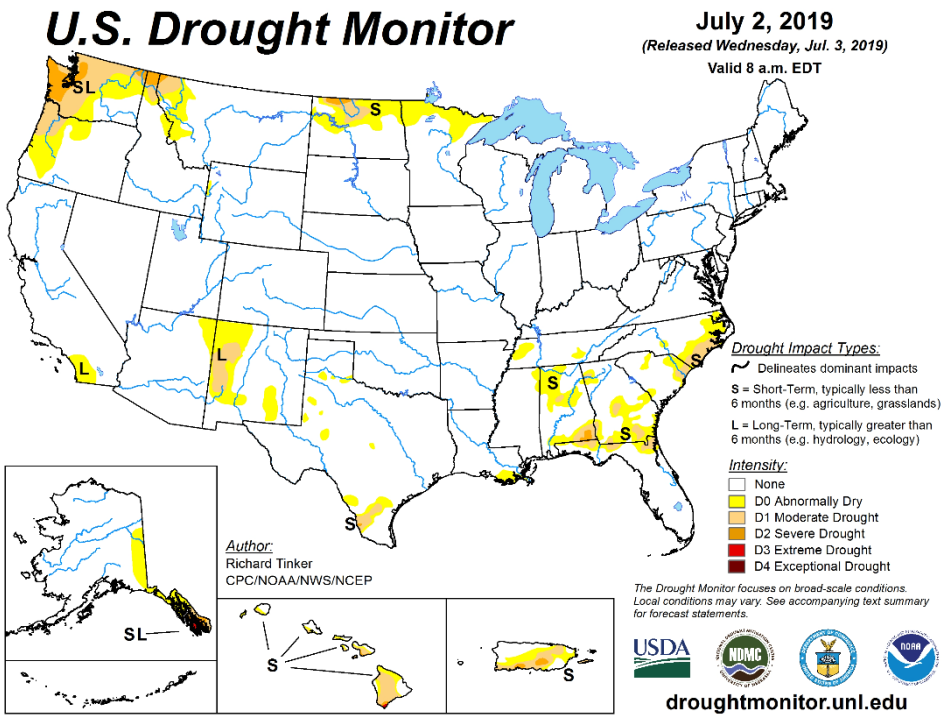


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for July 2, 2019.

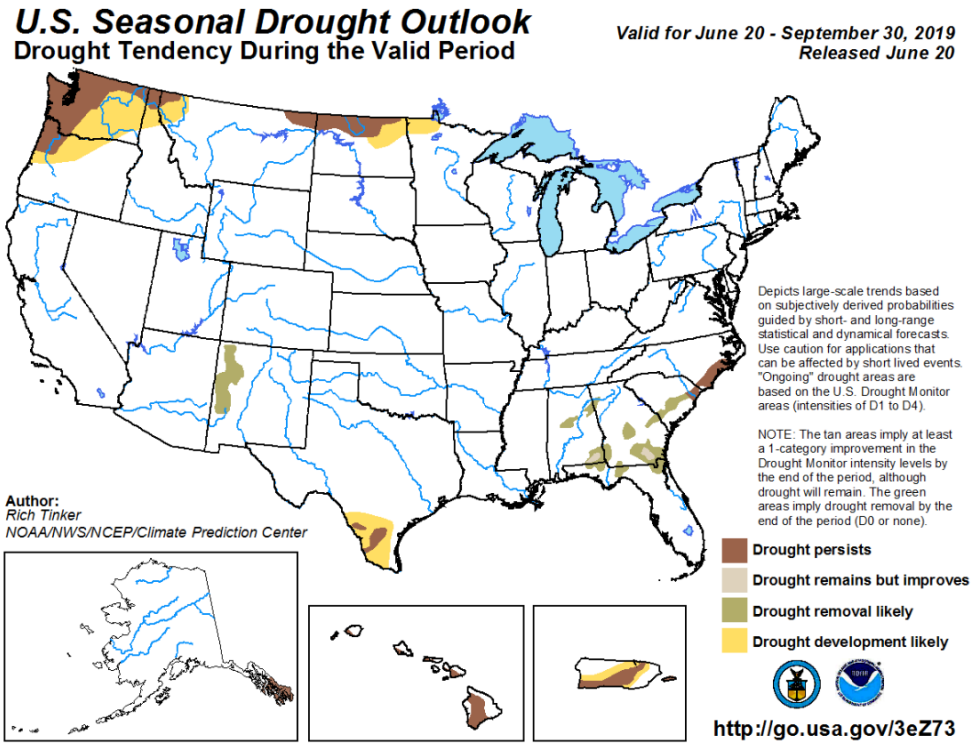


Figure 2. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. Precipitation as a percent of normal in June is shown in the left image of **Figure 3**, and April-May-June precipitation as a percent of normal is shown in the right image of **Figure 3**. June precipitation was much less than May precipitation. Areas of above-normal precipitation occurred in northern Montana, northwestern South Dakota, southern Nebraska, Kansas and western Missouri. It was greater than 150% of normal in northeastern Montana and northwestern South Dakota. Below-normal precipitation occurred in western Montana, central Wyoming, much of South Dakota, and western Iowa.

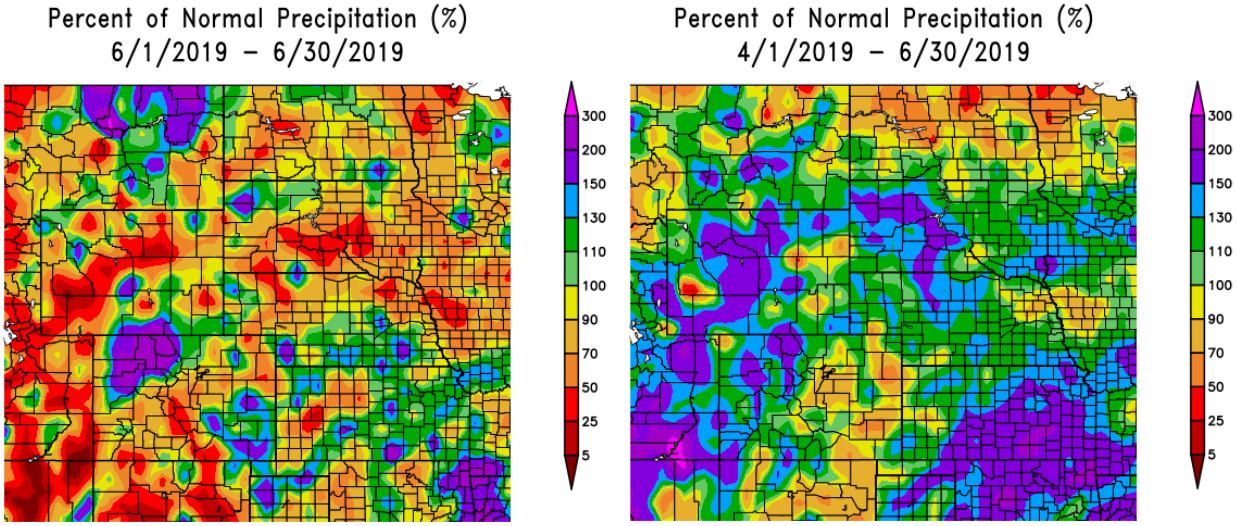


Figure 3. June 2019 and April-May-June 2019 Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Statewide precipitation rankings in **Figure 4** show that May 2019 was the wettest May in in 125 years of record-keeping in the states of Nebraska, Kansas, and Missouri, which subsequently continued to experience flooding in May and June. May precipitation in Wyoming, South Dakota, and Iowa was also much-above normal. The March – May precipitation rankings in **Figure 5** indicate the state of Kansas had the record wettest three-month period. South Dakota and Nebraska ranked 122nd and 123rd, respectively, on a scale where a 125 ranking is the wettest March – May.

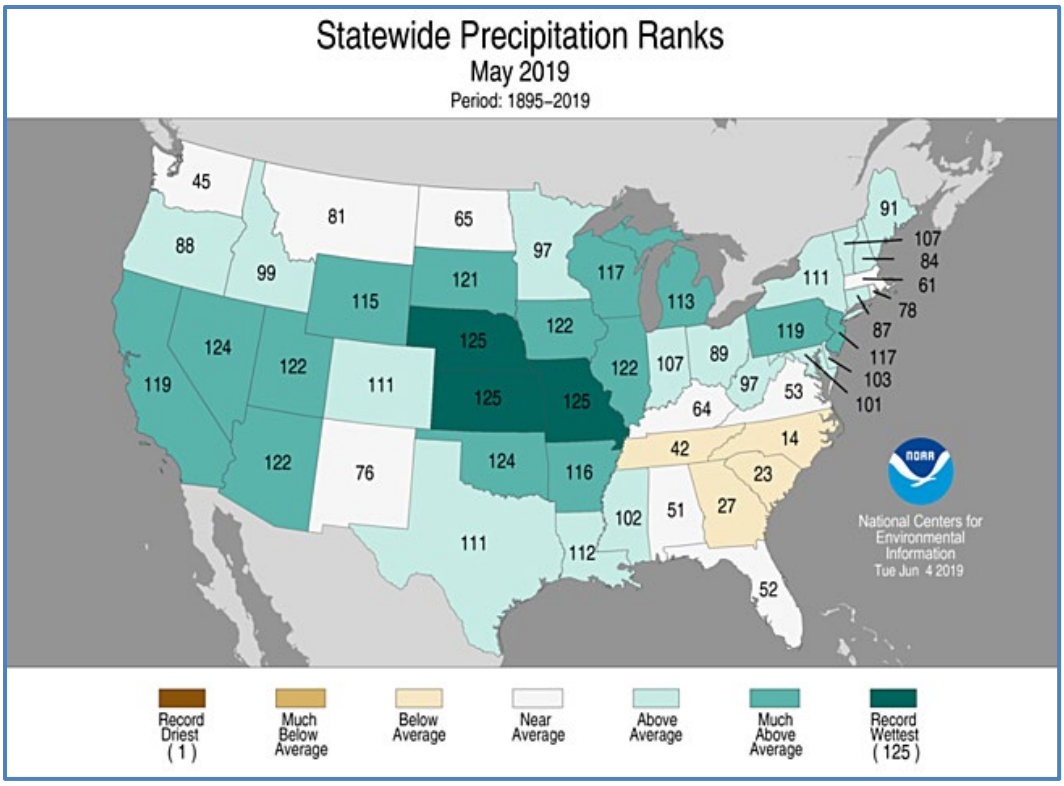


Figure 4. May 2019 Precipitation Statewide Ranking. Source: NOAA National Centers for Environmental Information, https://www.ncdc.noaa.gov/temp-and-precip/us-maps/1/201905?products[]=statewidepcpnrank#us-maps-select

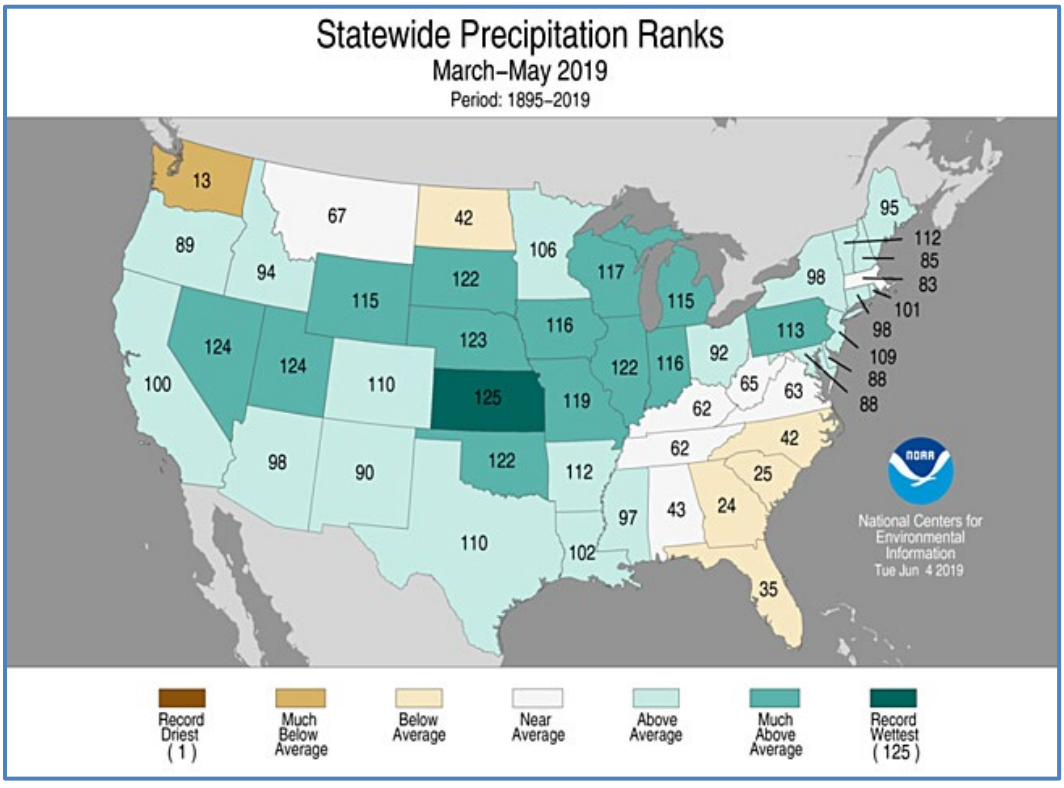


Figure 5. March-May 2019 Precipitation Statewide Ranking. Source: NOAA National Centers for Environmental Information, https://www.ncdc.noaa.gov/temp-and-precip/us-maps/3/201905?products[]=statewidepcpnrank#us-maps-select

Temperature departures for June are shown in degrees Fahrenheit (deg F) in the left image of **Figure 6**. June temperatures were within a few degrees of normal. Temperatures were slightly cooler than normal in Montana and Wyoming, and temperatures were about normal in most other areas. April-May-June temperature departures, shown in the right image of **Figure 6,** show the colder-than-normal temperature pattern that has impacted much of the Missouri Basin this spring**.** In most of the upper Basin, departures ranged from 1 to over 4 deg F below normal with some areas experience departures more than 5 deg F below normal.

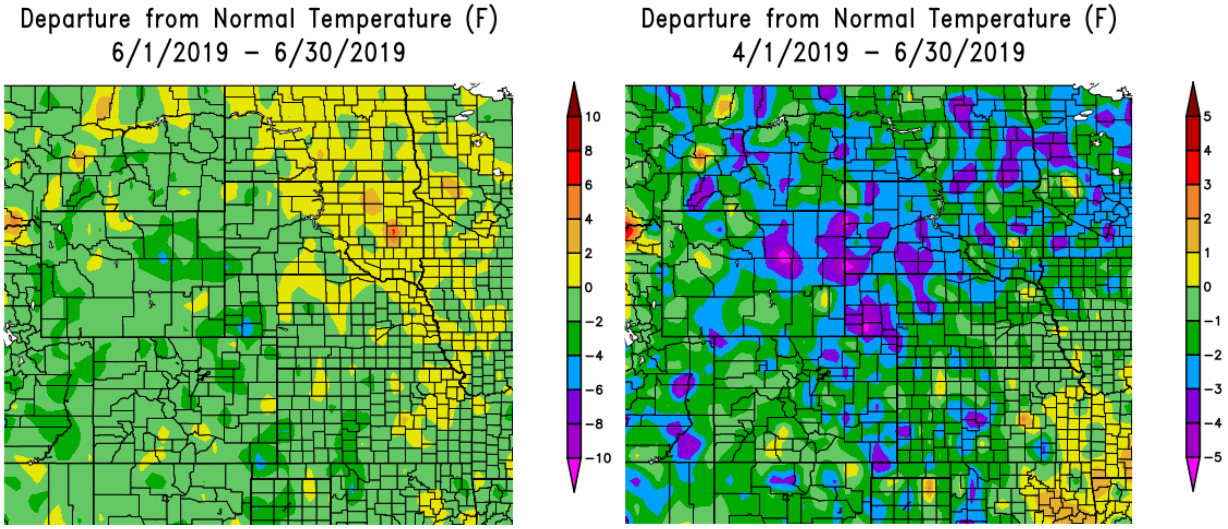


Figure 6. June 2019 and April-May-June 2019 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

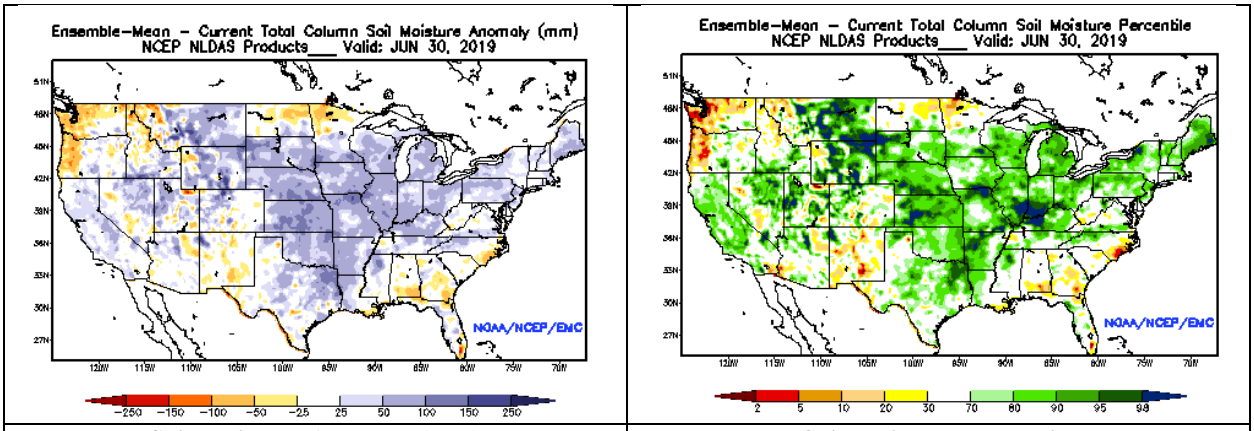
Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically, when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 7 shows the June 30, 2019 NOAA NLDAS ensemble soil moisture anomaly and soil moisture percentile. Based on the NLDAS soil moisture maps, soil moisture continues to be much wetter than normal, particularly in central and eastern Montana, eastern Wyoming, and northwestern South Dakota. Soil moisture is also wetter than normal in southern Nebraska, Kansas, and Missouri. Total soil moisture exceeds the 95th percentile in parts of Montana, northwestern South Dakota, southern Nebraska, Kansas, and northern Missouri. Consequently, these areas will be susceptible to above-average runoff and flooding if intense rainfall occurs.

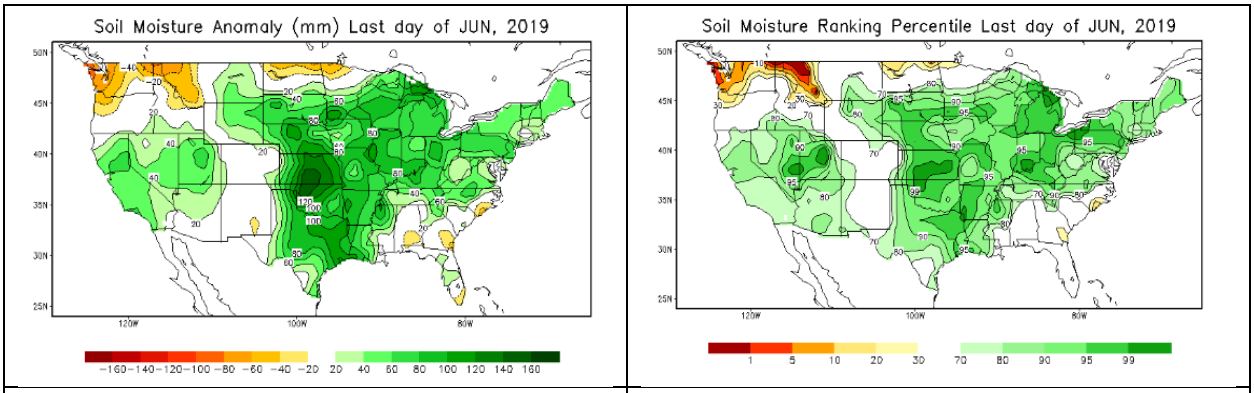
Figure 8 shows the June 30, 2019 NOAA CPC soil moisture anomaly and soil moisture percentile. The CPC map indicates soil moisture is particularly wet in southern South Dakota,

Nebraska and Kansas with soil moisture exceeding the 95th percentile in these areas. In contrast to the NLDAS maps, the CPC maps indicate that Montana and Wyoming soil moisture conditions are not nearly as wet as in the NLDAS maps. Nevertheless, much of the upper and lower Missouri Basin will be susceptible to above-average runoff and flooding based on the wetter-than-normal soil moisture conditions.



Soil Moisture Anomaly (mm) | **Soil Moisture Percentile**

Figure 7. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/



Soil Moisture Anomaly (mm) | **Soil Moisture Percentile**

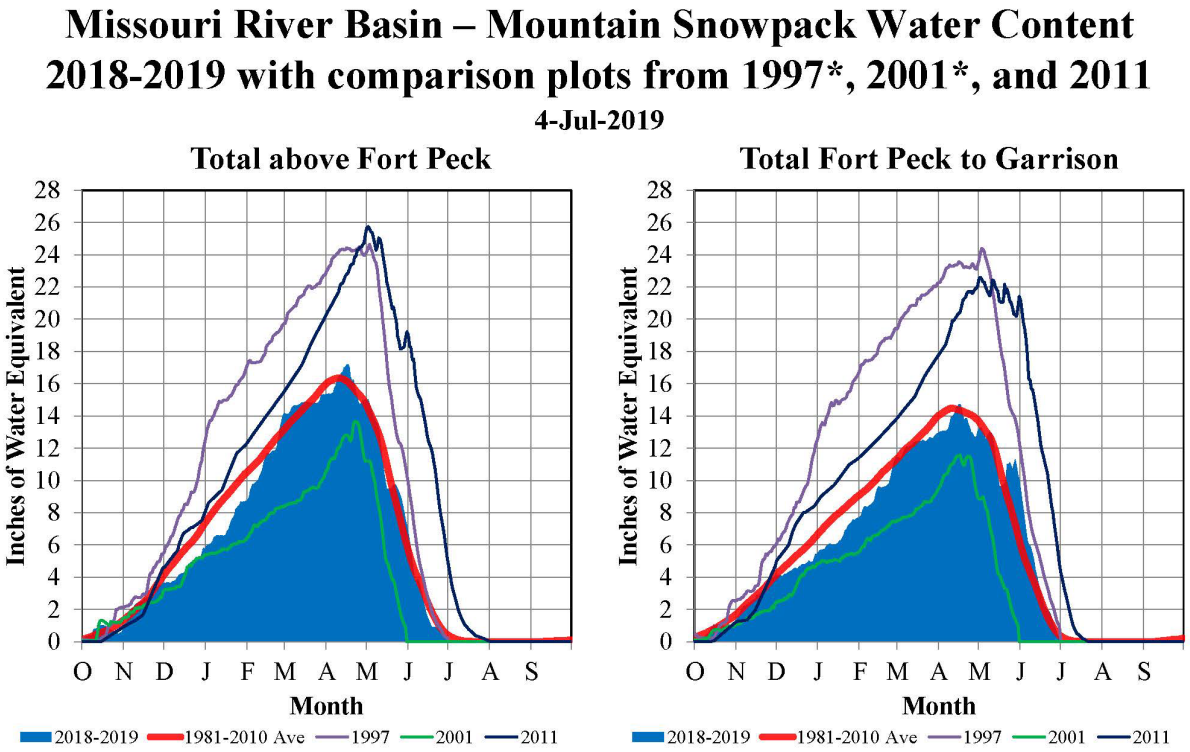
Figure 8. NOAA CPC Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA CPC. https://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reservoir reaches. It is typically NOT a factor influencing runoff at the beginning of a calendar year. **Figure 9** includes time series plots of the average mountain SWE beginning on October 1, 2018 based on the NRCS SNOTEL data for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

In the Fort Peck reservoir reach, mountain SWE peaked at 105% of average on April 18. In the Garrison reservoir reach, mountain SWE peaked at 104% of average on April 17. The melt occurred a bit slower than average due to the colder-than-normal temperatures in May and early June.

As of July 4, only small amounts of the winter's snowpack remained at the high elevation SNOTEL sites. In the Fort Peck reach, the mountain snowpack had effectively melted. In the Garrison reach, less than 1% of the peak accumulation remained.



The Missouri River Basin mountain snowpack normally peaks near April 15. On July 4, the mountain Snow Water Equivalent (SWE) in the "Total above Fort Peck" reach has melted. The "Total above Fort Peck" reach peaked at 17.2" on April 18, 105% of the normal April 15 peak. On July 4, the mountain SWE in the "Total Fort Peck to Garrison" reach was < 1", 13% of the July 4 average and < 1% of this year's peak remains. The snowpack in the "Total Fort Peck to Garrison" reach peaked at 14.9" on April 17, 104% of the normal April 15 peak.

Figure 9. Mountain snowpack water content on July 4, 2019 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The CPC's June 3, 2019 ENSO Outlook indicates that El Niño conditions are present. Per the CPC, El Niño conditions are predicted to persist through the Northern Hemisphere summer of 2019 (66% chance), with lower odds of continuing in the fall and winter (50-55% chance).

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

With regard to future weather, the CPC temperature outlook for July 12-18 (**Figure 10, left**) is indicating increased chances for above-normal temperatures over much of the Missouri Basin. Regarding precipitation (**Figure 10, right**), the CPC is indicating a very slight increase in the probability for above-normal precipitation in the plains, and equal chances for precipitation in western Montana, central Wyoming, and the lower Basin.

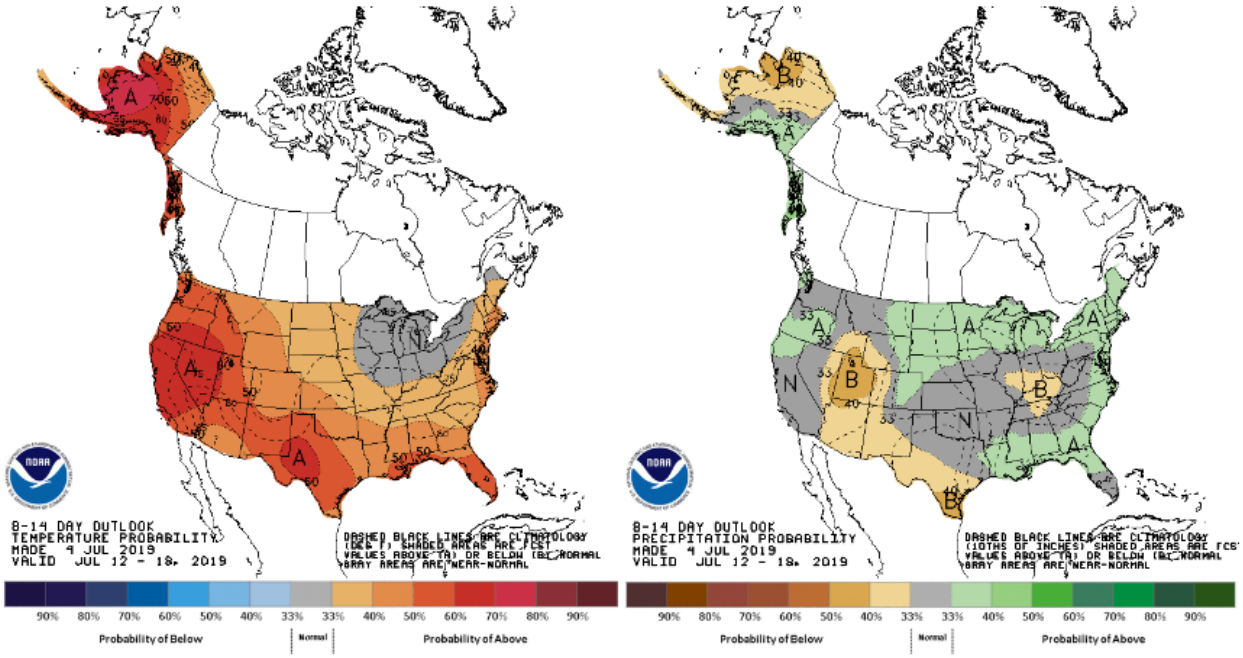


Figure 10. CPC 8-14 Day temperature and precipitation outlooks for July 12-18, 2019.

The July CPC outlooks in **Figure 11** indicate increased chances for below-normal temperatures over the central U.S., including much of the central and lower Missouri Basin. With regard to precipitation, the CPC is indicating increased chances for above-normal precipitation over much of the Missouri Basin, as a result of the cooler-than-normal temperatures and increased convective activity associated with El Niño summers.

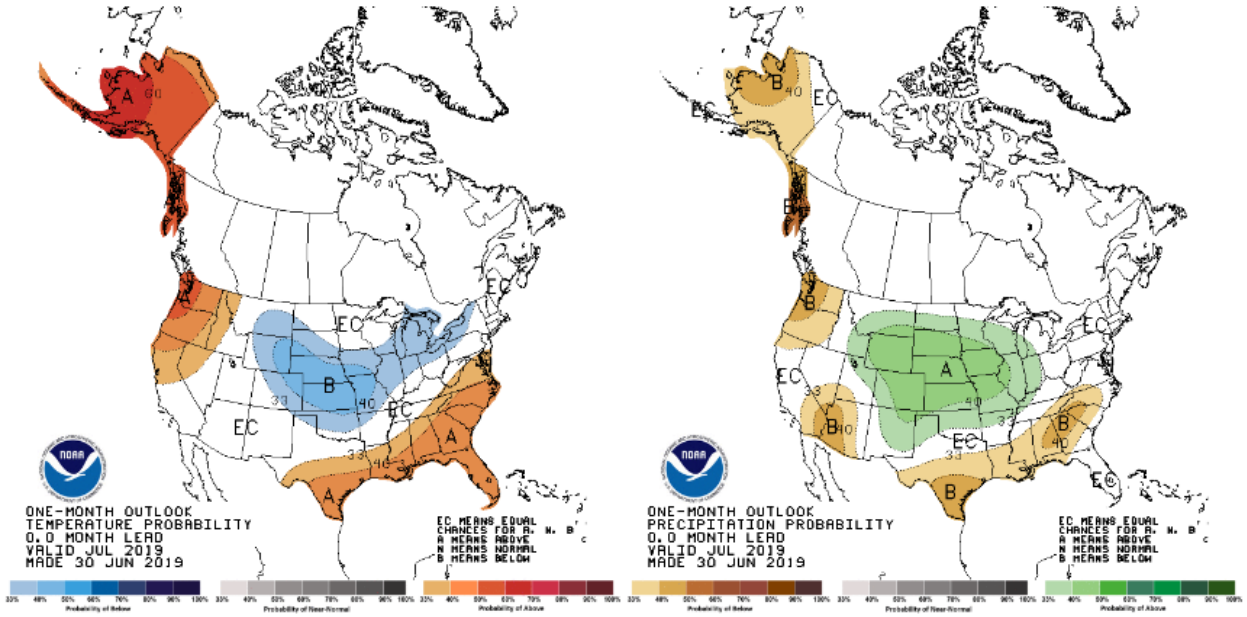


Figure 11. CPC July 2019 temperature and precipitation outlooks.

During the July-August-September 2019 period, the CPC outlooks in **Figure 12** are indicating increased chances for above-normal precipitation in most of the Missouri Basin. With regard to temperature, the CPC indicates equal chances for the central part of the Missouri basin, increased chances for below-normal temperatures in southeastern South Dakota, Nebraska, Iowa, Kansas, and Missouri, and increase chances for above-normal temperatures in Montana and western Wyoming.

During the October-November-December 2019 period, CPC outlooks in **Figure 13** indicate equal chances for precipitation over most of the Missouri Basin. The temperature outlook indicates increased chances for above-normal temperatures.

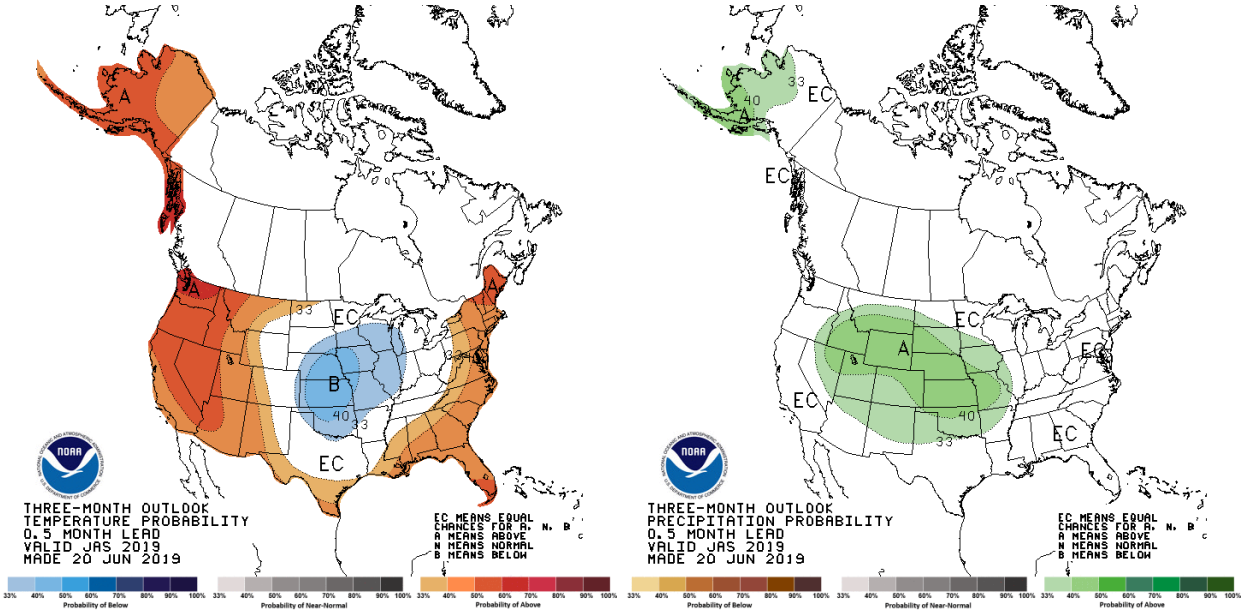


Figure 12. CPC July-August-September 2019 temperature and precipitation outlooks.

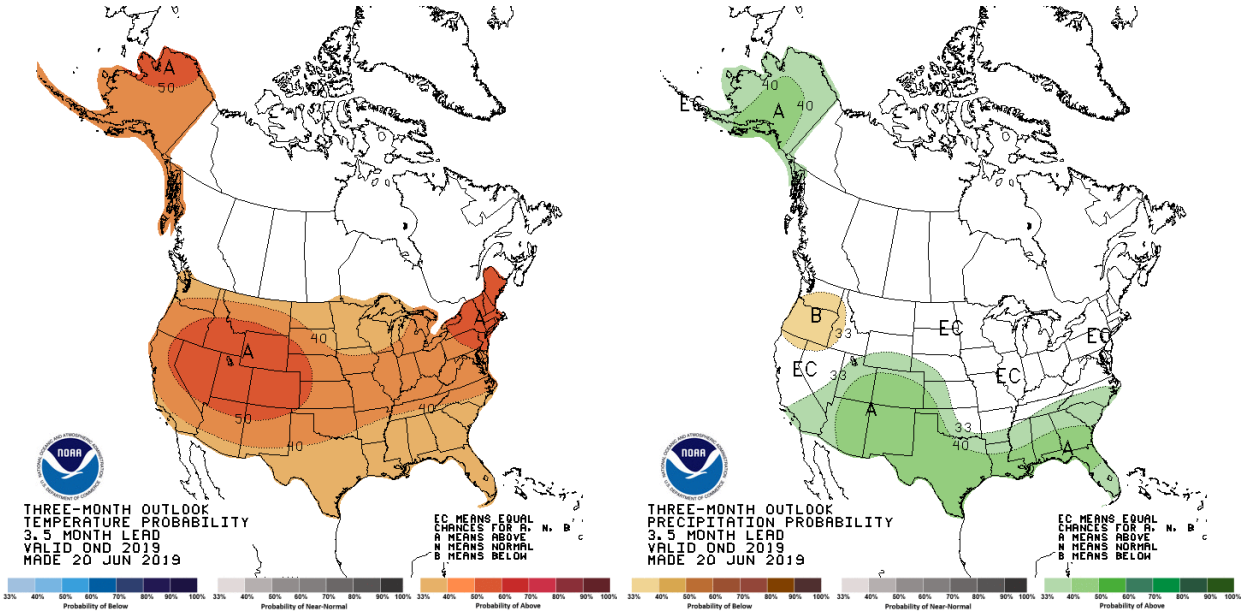


Figure 13. CPC October-November-December 2019 temperature and precipitation outlooks.

Summary

In summary, the updated 2019 calendar year runoff forecast is **49.9 MAF**, **197% of average**. Existing wet soil moisture conditions, high tributary baseflows, and forecasted summer and fall precipitation are major factors in determining the July 1 forecast. The Sioux City reach, which includes the James and Big Sioux River basins, is not regulated by the Mainstem System. This reach has been a major contributor to upper Basin runoff above Sioux City, and we expect it to contribute greatly to upper Basin runoff during the summer and fall.

Upper Missouri River Basin
August 2019 Calendar Year Runoff Forecast
August 5, 2019

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

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

July upper Basin runoff was 7.0 MAF, which is 213% of the monthly average. Runoff was well-above average in every reach. Fort Peck was 123% of average, Garrison was 155% of average, Oahe was 548% of average, Fort Randall was 729% of average, Gavins Point was 330% of average, and Sioux City was 496% of average. July precipitation was 200 to 300% of normal in areas of Montana, Wyoming, South Dakota, and Nebraska. To date, 45.3 MAF of runoff has occurred in the upper Basin, which is 229% of the normal August 1 volume.

2019 Calendar Year Forecast Synopsis

The 2019 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA is **52.9 MAF, 209% of average**. The 2019 calendar year runoff forecast above Gavins Point Dam, which does not include runoff from the James, Vermillion and Big Sioux rivers, is **41.5 MAF, 180% of average**. If realized, this would be the second highest runoff in 121 years of record-keeping, exceeding 1997's 49.0 MAF. The record is 61.0 MAF, set in 2011.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 5 months, expected inflow could range from the **55.0 MAF** upper basic forecast to the **50.9 MAF** lower basic forecast. The upper and lower basic forecasts are used in long-term

regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that five months are being forecast for this August 1 forecast (7 months observed/5 months forecast), the range of possible wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is attributed to all 6 reaches for the entire year, particularly as it relates to summer and fall precipitation. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for July 30, 2019 is shown in **Figure 1**. The drought monitor is available at http://droughtmonitor.unl.edu/. The Drought Monitor shows some isolated areas of Abnormal Dryness (D0) near Lake Sakakawea in North Dakota, near Omaha in Nebraska, and through areas of central Iowa. Only a small area of Moderate Drought (D1) is present north of Lake Sakakawea. Most of the Missouri Basin is unaffected by drought or abnormally dry conditions.

The Seasonal Drought Outlook in **Figure 2**, which extends through the end of October, indicates drought removal is likely for North Dakota, and no drought conditions are expected to develop by the end of October.

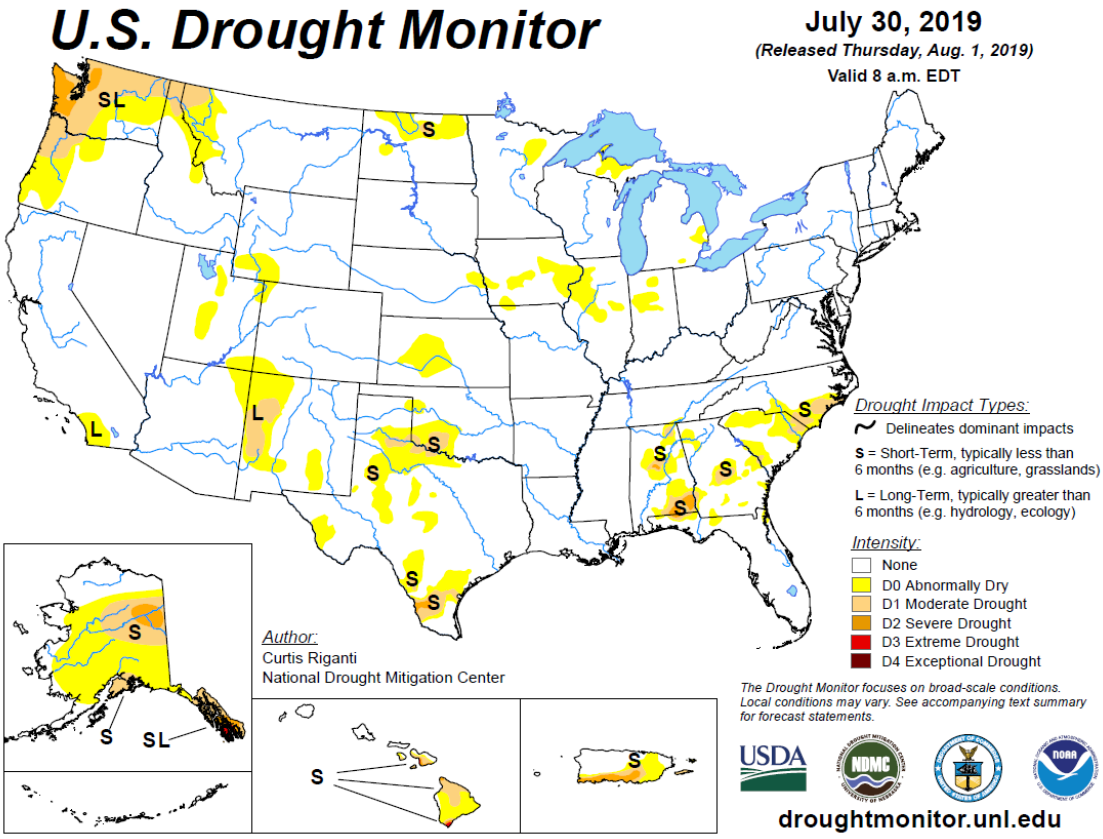


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for July 30, 2019.

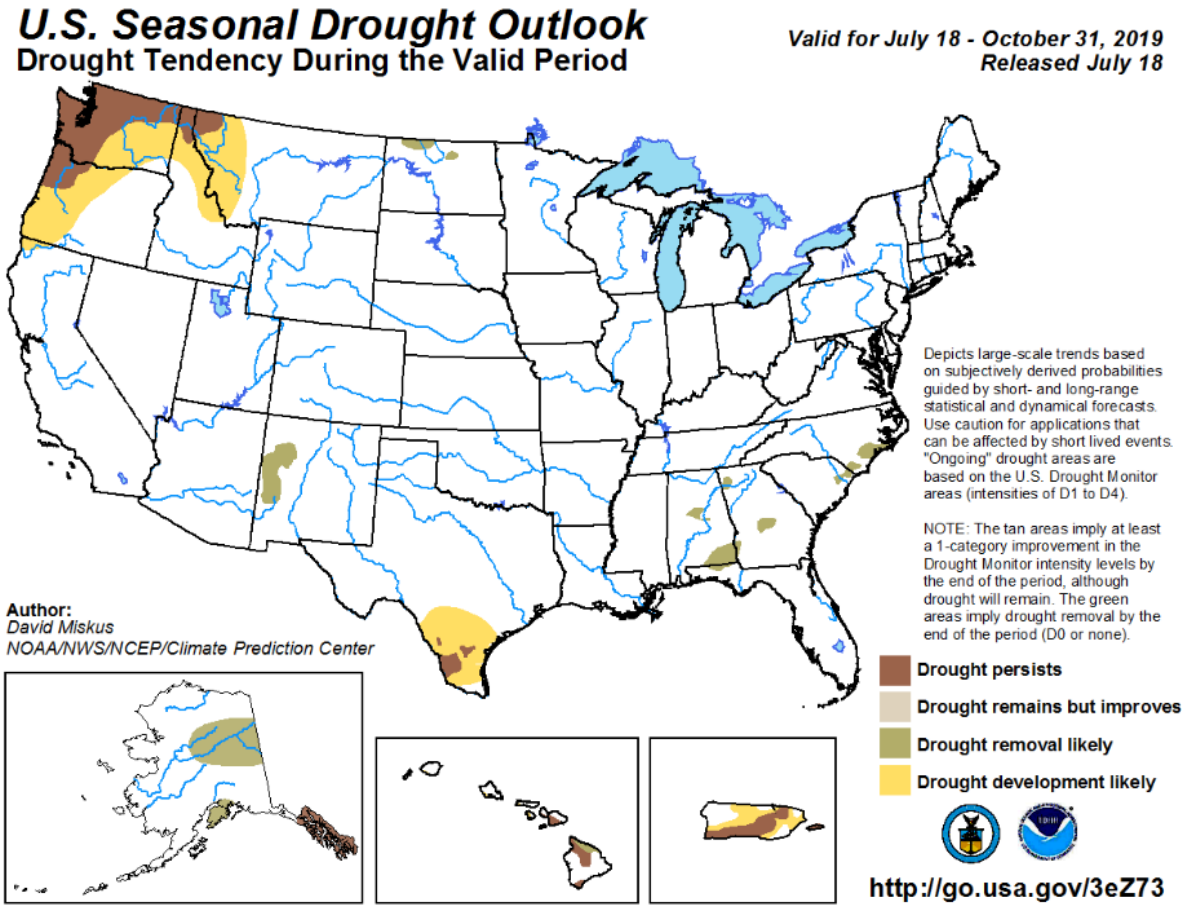


Figure 2. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. Precipitation as a percent of normal in July is shown in the left image of **Figure 3**, and May-June-July precipitation as a percent of normal is shown in the right image of **Figure 3**. July precipitation was 150% to greater than 300% of normal in southern Montana, northern Wyoming, South Dakota, central North Dakota, and central Nebraska. Below-normal precipitation occurred in northern Montana, southern Wyoming, Colorado, northeastern North Dakota, eastern Nebraska, Kansas, and Iowa. An above-normal three-month precipitation pattern can be seen from southern Montana extending southeast all the way into Kansas and Missouri.

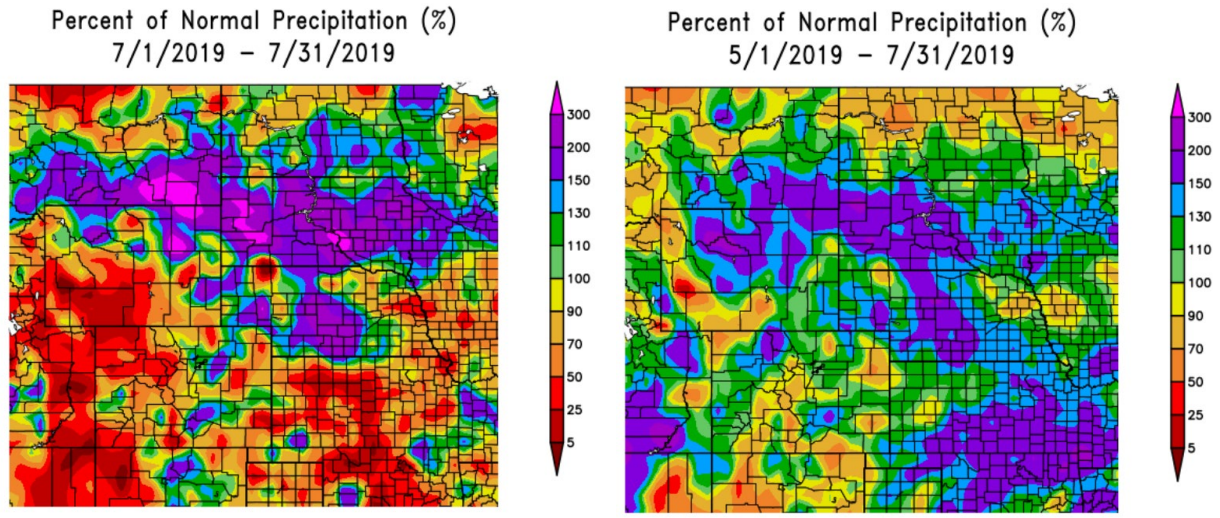


Figure 3. July 2019 and May-June-July 2019 Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature departures for July are shown in degrees Fahrenheit (deg F) in the left image of **Figure 4**. July temperatures were within a few degrees of normal. May-June-July temperature departures, shown in the right image of **Figure 4,** show the colder-than-normal temperature pattern that has impacted much of the Missouri Basin this spring**.** In most of the upper Basin, departures ranged from 1 to over 4 deg F below normal with some areas experiencing departures more than 5 deg F below normal.

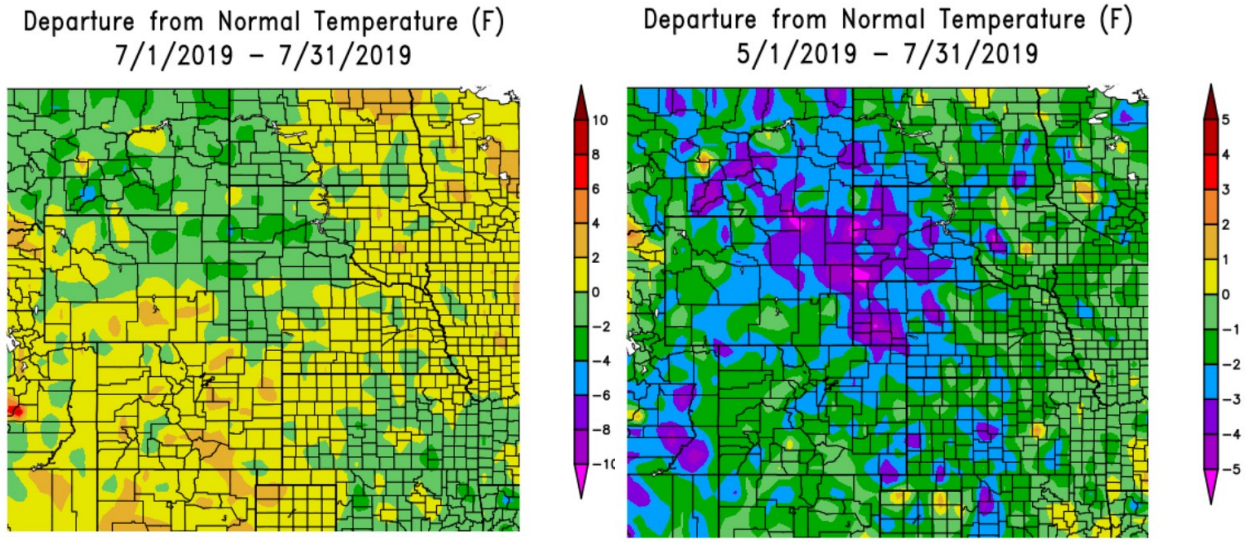


Figure 4. July 2019 and May-June-July 2019 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and

snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 5 shows the August 1, 2019 NOAA NLDAS ensemble soil moisture anomaly and soil moisture percentile. Based on the NLDAS soil moisture maps, soil moisture continues to be much wetter than normal, particularly in central and eastern Montana, eastern Wyoming, South Dakota, and Nebraska. Soil moisture is also wetter than normal in Kansas and Missouri. Total soil moisture exceeds the 95th percentile in parts of Montana and South Dakota. Consequently, these areas will be susceptible to above-average runoff and flooding if intense rainfall occurs. Soil moisture is drier than normal in northeastern North Dakota.

Figure 6 shows the July 31, 2019 NOAA CPC soil moisture anomaly and soil moisture percentile. The CPC map indicates soil moisture is particularly wet in South Dakota, Nebraska, Kansas, Iowa, Missouri, southeastern Montana, northeastern Wyoming, and southern North Dakota. Like the NLDAS maps, the CPC maps indicate soils are drier than normal in northern North Dakota. Nevertheless, much of the upper and lower Missouri Basin will be susceptible to above-average runoff and flooding based on the wetter-than-normal soil moisture conditions.

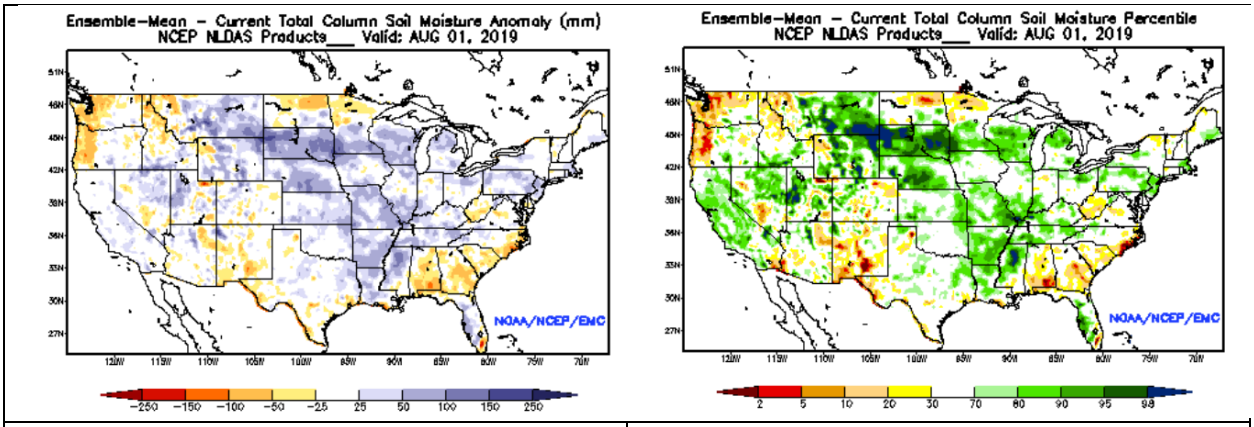


Figure 5. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

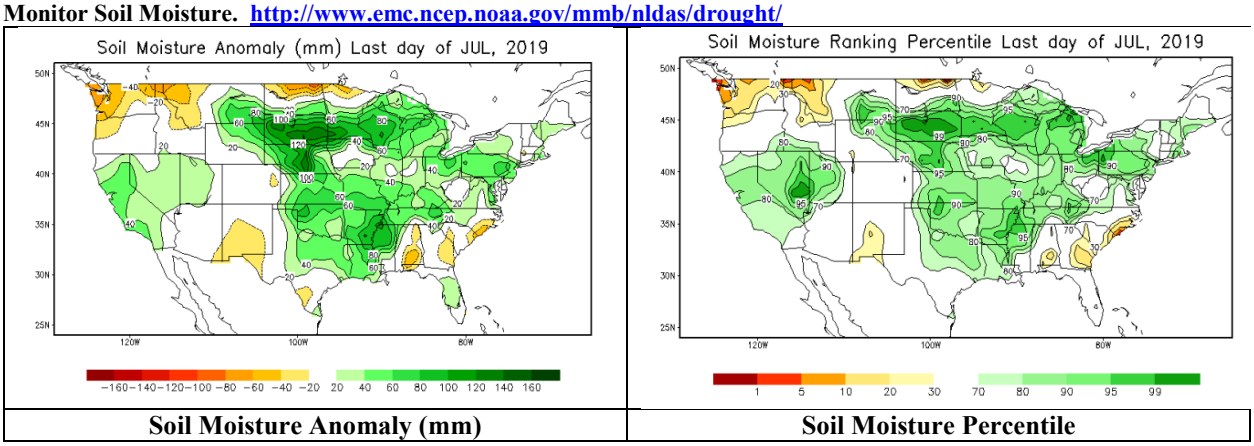


Figure 6. NOAA CPC Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA CPC. https://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reservoir reaches. It is typically NOT a factor influencing runoff at the beginning of a calendar year. **Figure 7** includes time series plots of the average mountain SWE beginning on October 1, 2018 based on the NRCS SNOTEL data for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

In the Fort Peck reservoir reach, mountain SWE peaked at 105% of average on April 18. In the Garrison reservoir reach, mountain SWE peaked at 104% of average on April 17. The melt occurred a bit slower than average due to the colder-than-normal temperatures in May and early June.

By July 8, the remaining SWE in both reaches had melted out.

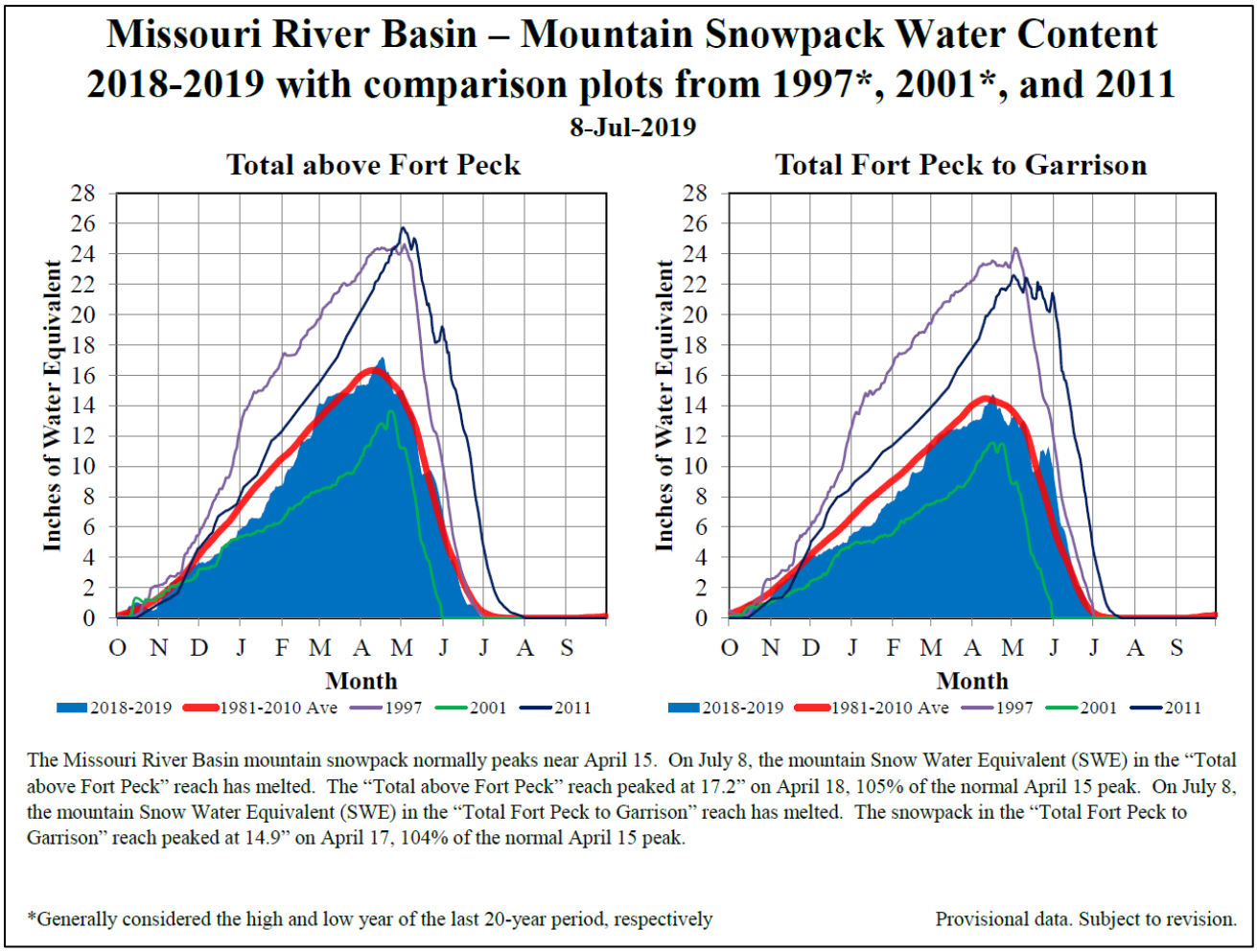


Figure 7. Mountain snowpack water content on July 8, 2019 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The CPC's August 5, 2019 ENSO Outlook indicates that El Niño conditions are present. Per the CPC, El Niño conditions are predicted to persist through the Northern Hemisphere summer of 2019, with a transition to ENSO-neutral in the next month or two. ENSO-neutral conditions are likely to persist through the Northern Hemisphere fall and winter.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

With regard to future weather, the CPC temperature outlook for August 13-19 (**Figure 8, left**) is indicating increased chances for below-normal temperatures over much of the upper Missouri Basin. Regarding precipitation (**Figure 8, right**), the CPC is indicating a very slight increase in the probability for above-normal precipitation in the plains and lower Basin, with a slight increase in the probability for below-normal precipitation in the mountains.

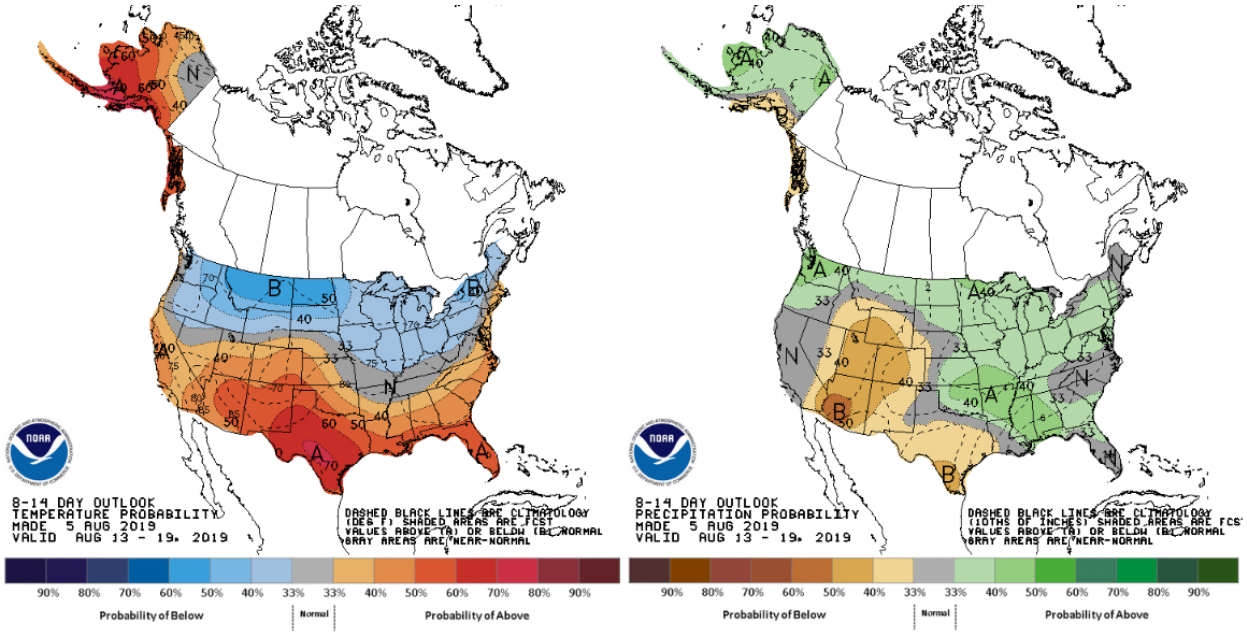


Figure 8. CPC 8-14 Day temperature and precipitation outlooks for August 13-19, 2019.

The August CPC outlooks in **Figure 9** indicate increased chances for below-normal temperatures over the central U.S., including much of the central and lower Missouri Basin. With regard to precipitation, the CPC is indicating increased chances for above-normal precipitation over much of the Missouri Basin.

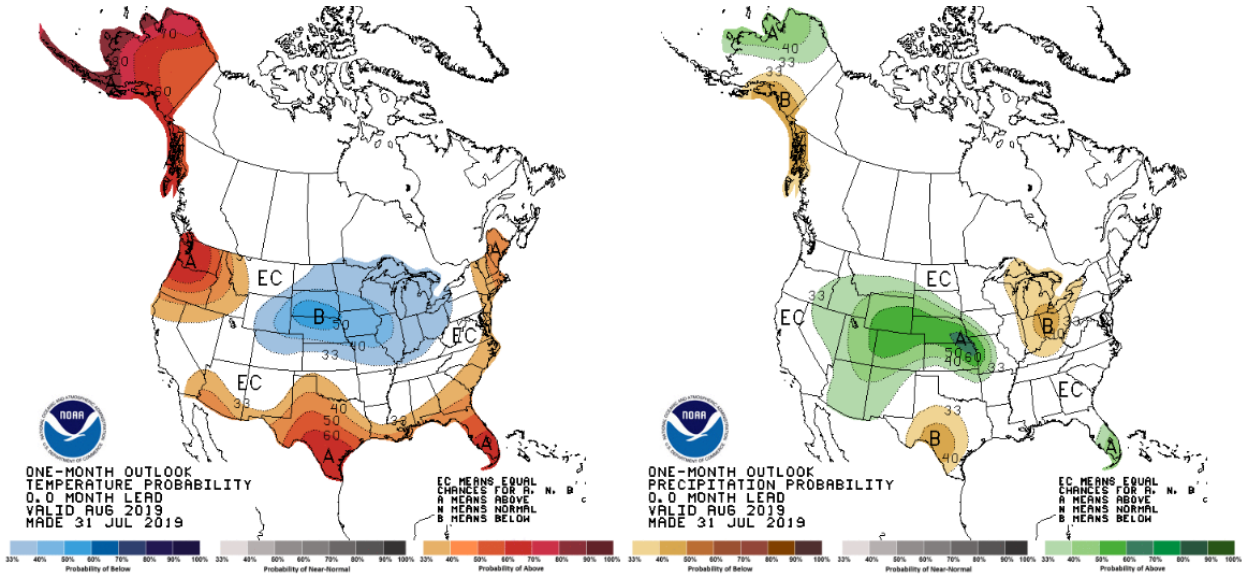


Figure 9. CPC August 2019 temperature and precipitation outlooks.

During the August-September-October 2019 period, the CPC outlooks in **Figure 10** are indicating increased chances for above-normal precipitation in most of the Missouri Basin. With regard to temperature, the CPC indicates equal chances for the central part of the Missouri Basin,

with increased chances for above-normal temperatures in the mountains and southwestern Kansas.

During the November-December 2019-January 2020 period, CPC outlooks in **Figure 11** indicate equal chances for precipitation over most of the Missouri Basin. The temperature outlook indicates increased chances for above-normal temperatures.

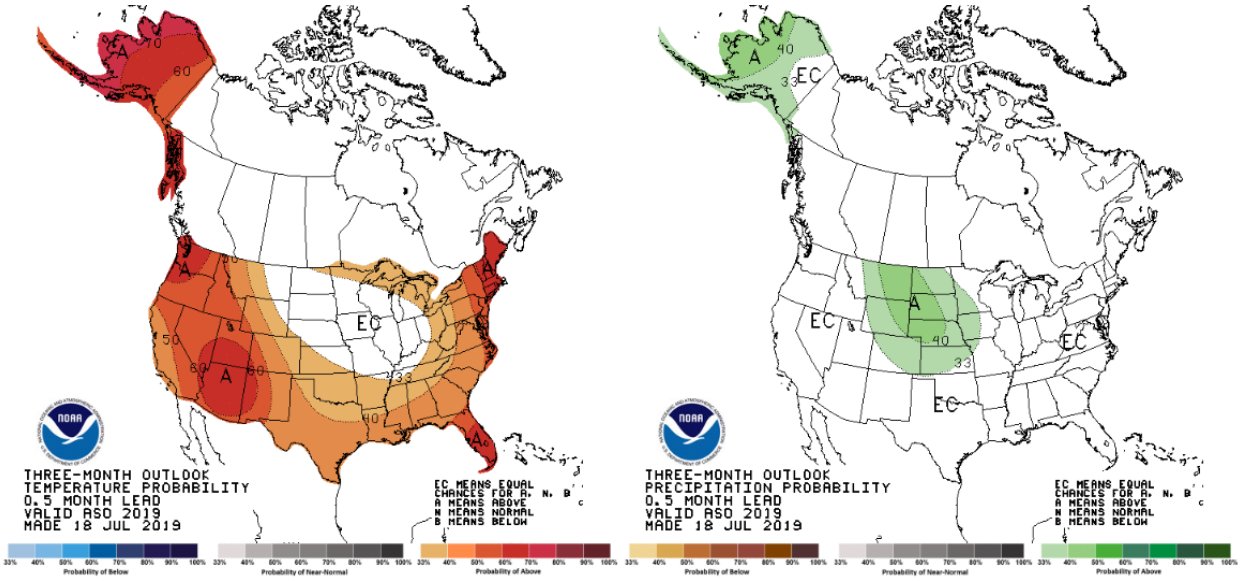


Figure 10. CPC August-September-October 2019 temperature and precipitation outlooks.

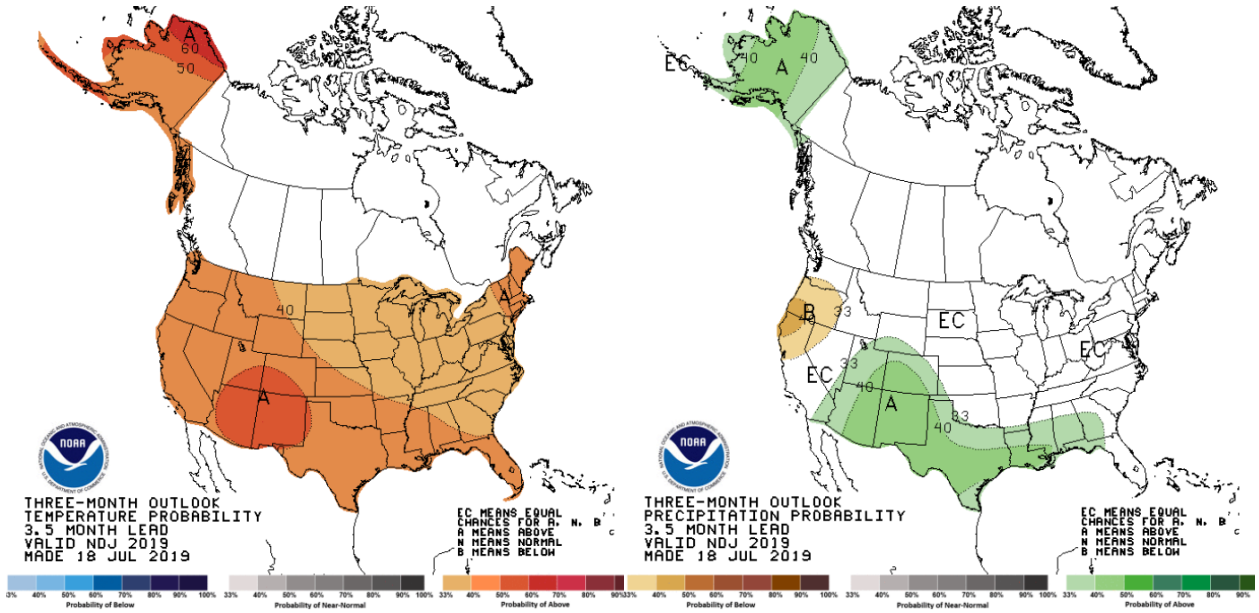


Figure 11. CPC November-December 2019-January 2020 temperature and precipitation outlooks.

Summary

In summary, the updated 2019 calendar year runoff forecast is **52.9 MAF**, **209% of average**. Existing wet soil moisture conditions, high tributary baseflows, and forecasted summer and fall precipitation are major factors in determining the August 1 forecast. The Sioux City reach, which includes the James and Big Sioux River basins, is not regulated by the Mainstem System. This reach has been a major contributor to upper Basin runoff above Sioux City, and we expect it to contribute greatly to upper Basin runoff during the summer and fall.

Upper Missouri River Basin
September 2019 Calendar Year Runoff Forecast
September 9, 2019

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

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

August upper Basin runoff was 3.3 MAF (**Table 1**), which is 245% of the monthly average. July precipitation was more than 150% of normal in areas of eastern Montana, North Dakota, South Dakota, Nebraska, Kansas and Missouri. As a result, August runoff was more than six times the average runoff in the Oahe reach, more than ten times the average runoff in the Fort Randall reach, nearly three times the average runoff in the Gavins Point reach, and more than five times the average runoff in the Sioux City reach. Monthly runoff volumes in the Fort Randall and Gavins Point reaches exceeded the previous record highest in August, while monthly runoff in the Sioux City reach was the second highest, and monthly runoff in the Oahe reach was third highest on record.

Accumulated runoff as of September 1, 2019 (January through August) was 48.7 MAF (**Table 1**). Runoff in 2019 will soon exceed the 1997 total runoff volume of 49.0 MAF, which was the second highest runoff volume in 121 years of record-keeping. Accumulated runoff in the lower four reaches (Oahe, Fort Randall, Gavins Point and Sioux City reaches) have exceeded the previous January – August maximum accumulation. Previous maximum January – August accumulations occurred in 2011 (the record highest runoff year) in the Fort Peck, Garrison, and Sioux City reaches, and in 1997 (the second highest runoff year) in the Oahe, Fort Randall, and

Gavins Point reaches. More significantly, accumulated runoff in the four lower reaches is greater than the maximum January - December observed runoff in 121 years of record-keeping, and runoff is still accumulating with four months remaining in the calendar year.

Table 1. August and January-August runoff volumes compared to historic maximum runoff volumes.

Reach	August Runoff, kAF			Accumulated Runoff, kAF		
	2019 (% of average)	Average	Maximum (year)	2019 Jan-Aug	Maximum Jan-Aug (year)	Maximum Jan-Dec (year)
Fort Peck	384 (107%)	360	981 (1993)	7,730	12,972 (2011)	14,477 (2011)
Garrison	764 (125%)	613	1,542 (2011)	13,588	22,373 (2011)	24,512 (2011)
Oahe	503 (620%)	81	697 (2014)	7,821**	7,560 (1997)	7,560 (2009)
Fort Randall	488 (1134%)*	43	243 (2011)	5,003**	3,256 (1997)	3,432 (1997)
Gavins Point	318 (274%)*	116	308 (1975)	3,814**	2,728 (1997)	3,573 (1997)
Sioux City	884 (581%)	152	1,272 (2010)	10,698**	9,030 (2011)	10,557 (2010)
Summation	3,340 (245%)	1,365	n/a	48,654	54,905 (2011)	61,004 (2011)

* Indicates record highest August runoff volume.
** Indicates record highest January – August accumulated runoff and January – December runoff.

2019 Calendar Year Forecast Synopsis

The 2019 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA is **54.6 MAF, 215% of average**. The 2019 calendar year runoff forecast above Gavins Point Dam, which does not include runoff from the James, Vermillion and Big Sioux rivers, is **42.5 MAF, 184% of average**. The 2019 calendar year runoff forecast is on track to be the second highest runoff year in 121 years of record-keeping, exceeding 1997's 49.0 MAF. The record is 61.0 MAF, set in 2011.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next four months, expected inflow could range from the **56.2 MAF** upper basic forecast to the **53.2 MAF** lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that four months are being forecast for this September 1 forecast (8 months observed/4 months forecast), the range of possible wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is attributed to all six reaches for the entire year, particularly as it relates to summer and fall precipitation. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for September 3, 2019 is shown in **Figure 1**. The drought monitor is available at http://droughtmonitor.unl.edu/. The Drought Monitor shows some isolated areas of Abnormal Dryness (D0) in northwestern Montana, northeastern Nebraska and northwestern Iowa. There are currently no areas in the Missouri River Basin in a drought classification (D1 – D4).

The Seasonal Drought Outlook in **Figure 2**, which extends through the end of November, indicates no changes to drought conditions in the Missouri Basin during the forecast period.

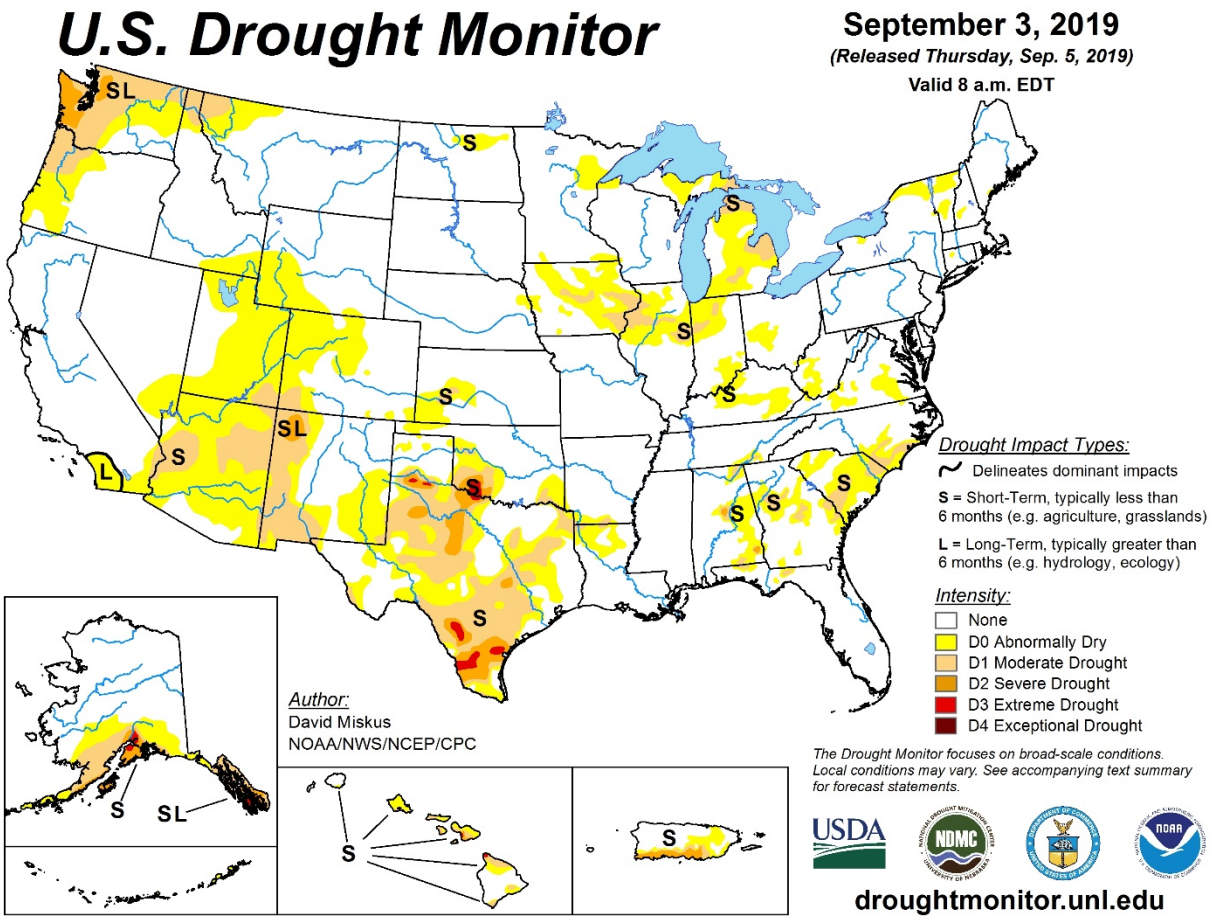


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for September 3, 2019.

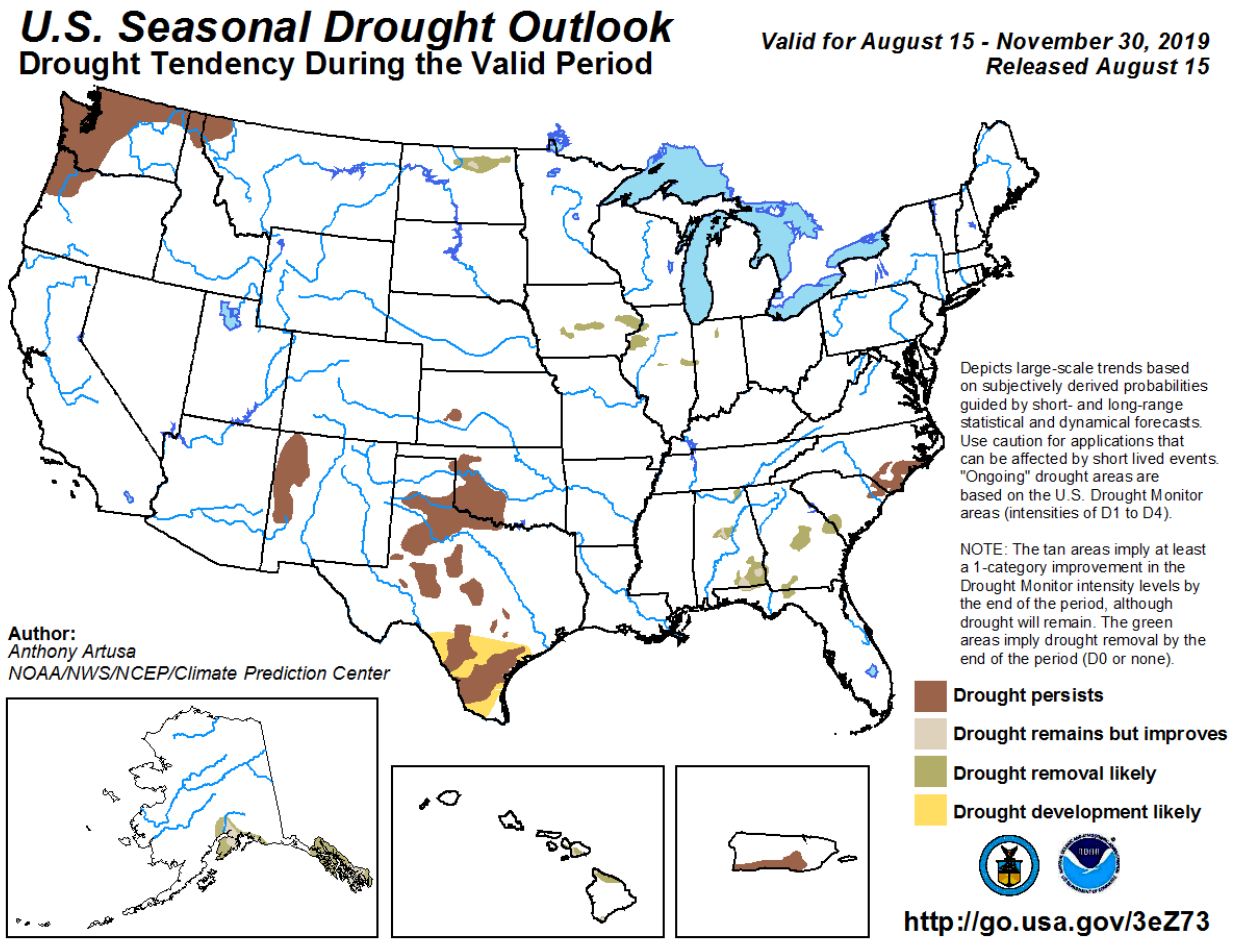


Figure 2. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. Precipitation as a percent of normal in August is shown in the top image of **Figure 3**, and June-July-August precipitation as a percent of normal is shown in the bottom image of **Figure 3**. August precipitation was greater than 150% of normal in eastern Montana, portions of North Dakota, much of South Dakota and Nebraska. Some areas of greater than 300% of normal precipitation occurred in south central South Dakota, eastern Wyoming, central Nebraska, central and eastern Kansas. The very high August precipitation resulted in record high runoff volumes in the Fort Randall and Gavins Point reaches, as well as high river flows in the Platte River, the lower Kansas River, and the lower Missouri River. The three-month precipitation as a percent of normal image shows that precipitation was well-above normal throughout eastern Montana, North Dakota, South Dakota, much of Kansas, Nebraska and Missouri.

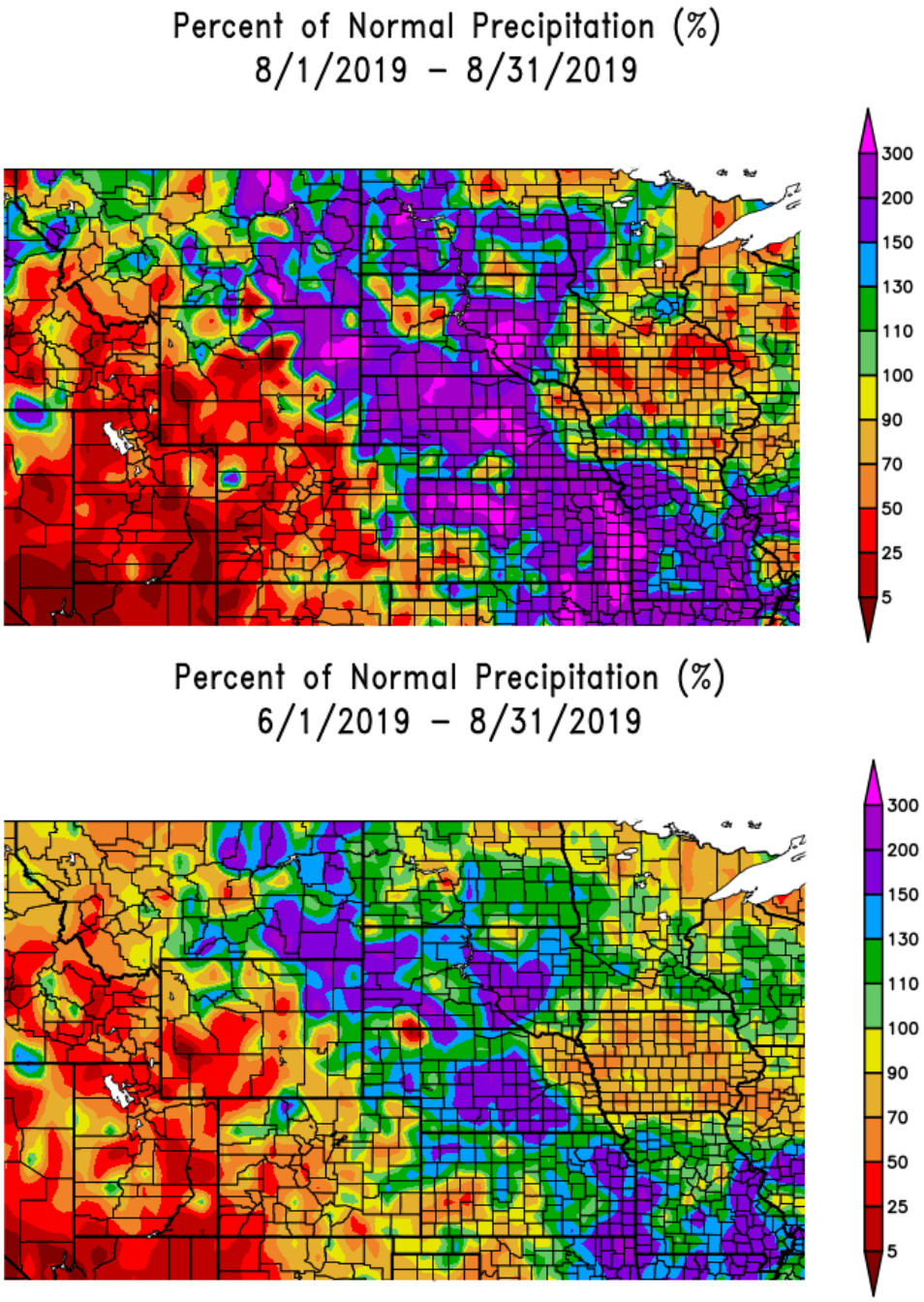


Figure 3. August 2019 and June-July-August 2019 Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature departures for August are shown in degrees Fahrenheit (deg F) in the top image of **Figure 4**. August temperatures ranged from 2 to 5 deg F below normal in North Dakota and South Dakota. In other areas of the upper Basin, temperatures were 1 to 2 deg F below normal. In contrast, temperatures were slightly above normal in western Montana and Wyoming. June-July-August temperature departures, shown in the top image of **Figure 4,** show a slightly colder-than-normal temperature pattern that has impacted much of the Missouri Basin this summer**.** In most of the upper Basin, departures ranged from 1 to 3 deg F below normal.

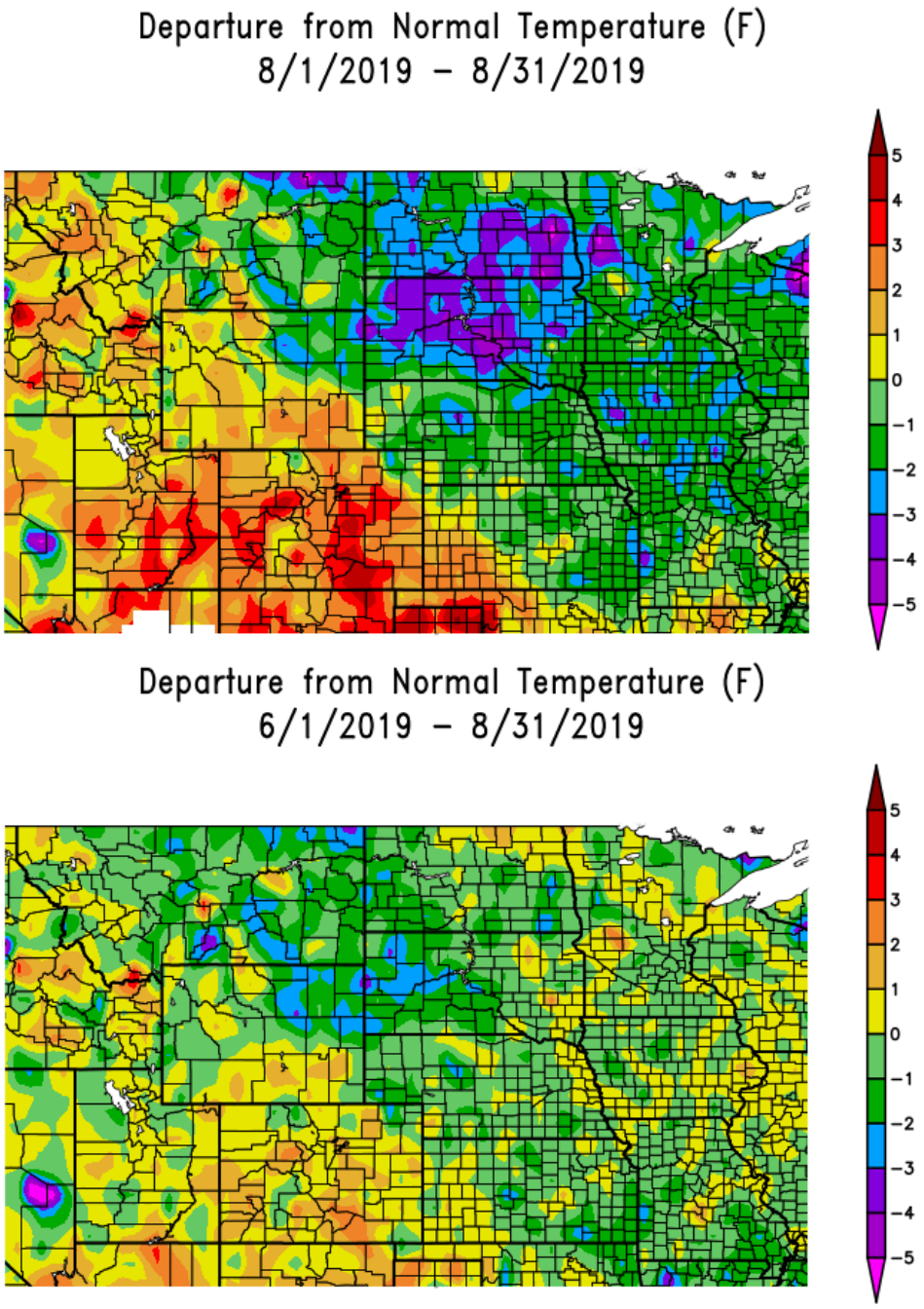


Figure 4. August 2019 and June-July-August 2019 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 5 shows the September 5, 2019 NOAA NLDAS ensemble soil moisture anomalies and soil moisture percentiles. Based on the NLDAS soil moisture anomaly map, soil moisture anomalies are well above normal, particularly in central and eastern Montana, eastern Wyoming, South Dakota, Nebraska, Kansas and Missouri. In terms of percentile, total soil moisture exceeds the 98th percentile, which is very wet, in parts of southeastern Montana, South Dakota, Nebraska, eastern Kansas and western Missouri. Consequently, these areas will be susceptible to above-average runoff and flooding if intense rainfall occurs.

Figure 6 shows the August 31, 2019 NOAA CPC soil moisture anomalies and soil moisture percentiles. The CPC maps indicate soil moisture is particularly wet in South Dakota, central Nebraska, and eastern Kansas. Similar to the NLDAS maps, most of the Missouri Basin is wetter than normal in terms of soil moisture.

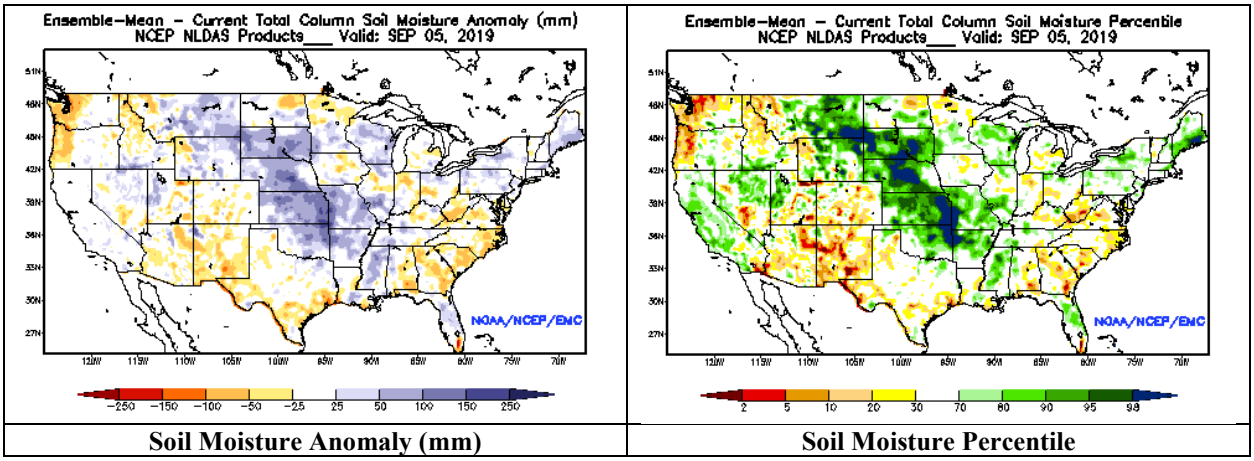


Figure 5. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

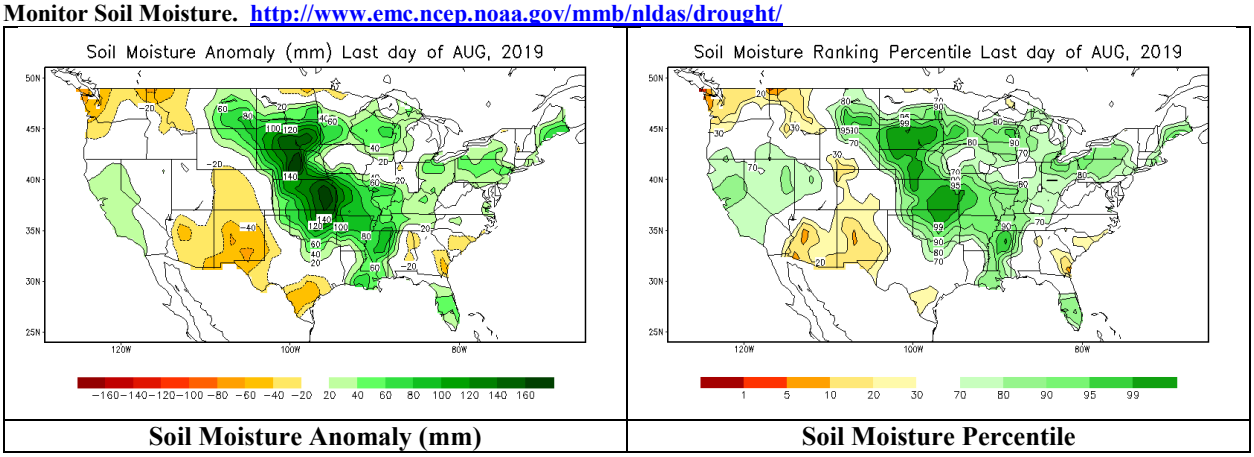


Figure 6. NOAA CPC Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA CPC. https://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The CPC's September 2, 2019 ENSO Outlook indicates that ENSO-neutral conditions are present. Equatorial sea surface temperatures are above average across the western Pacific Ocean, and below average across the eastern Pacific Ocean. ENSO-neutral conditions are most likely to continue through the Northern Hemisphere winter of 2019-20, with a 50-55% chance.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

With regard to future weather, the CPC temperature outlook for September 15-19 (**Figure 7, left**) is indicating increased chances for above-normal temperatures over much of the Missouri Basin. Regarding precipitation (**Figure 7, right**), the CPC is indicating increased chances for above-normal precipitation in the upper Basin, with at least a 50% chance for above-normal precipitation in central and western Montana.

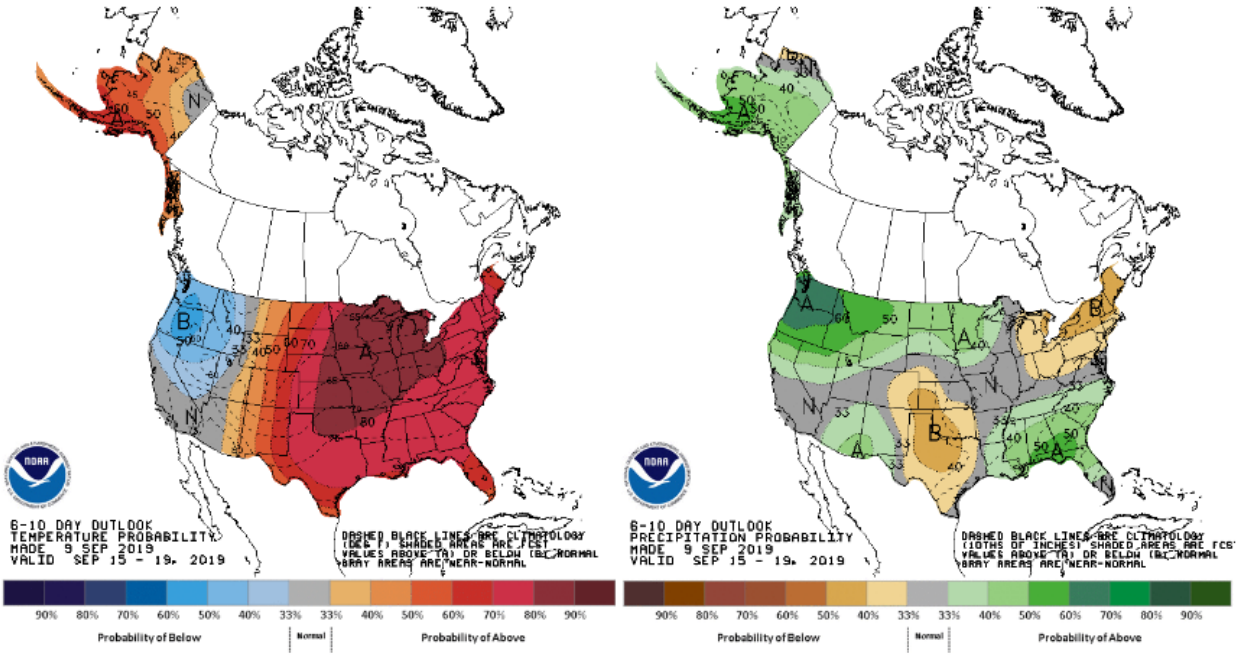


Figure 7. CPC 8-14 Day temperature and precipitation outlooks for September 15-19, 2019.

The September CPC outlooks in **Figure 8** indicate increased chances for below-normal temperatures over the north-central U.S., including much of the Dakotas, Nebraska and western Iowa. With regard to precipitation, the CPC is indicating increased chances for above-normal precipitation over much of the Missouri Basin.

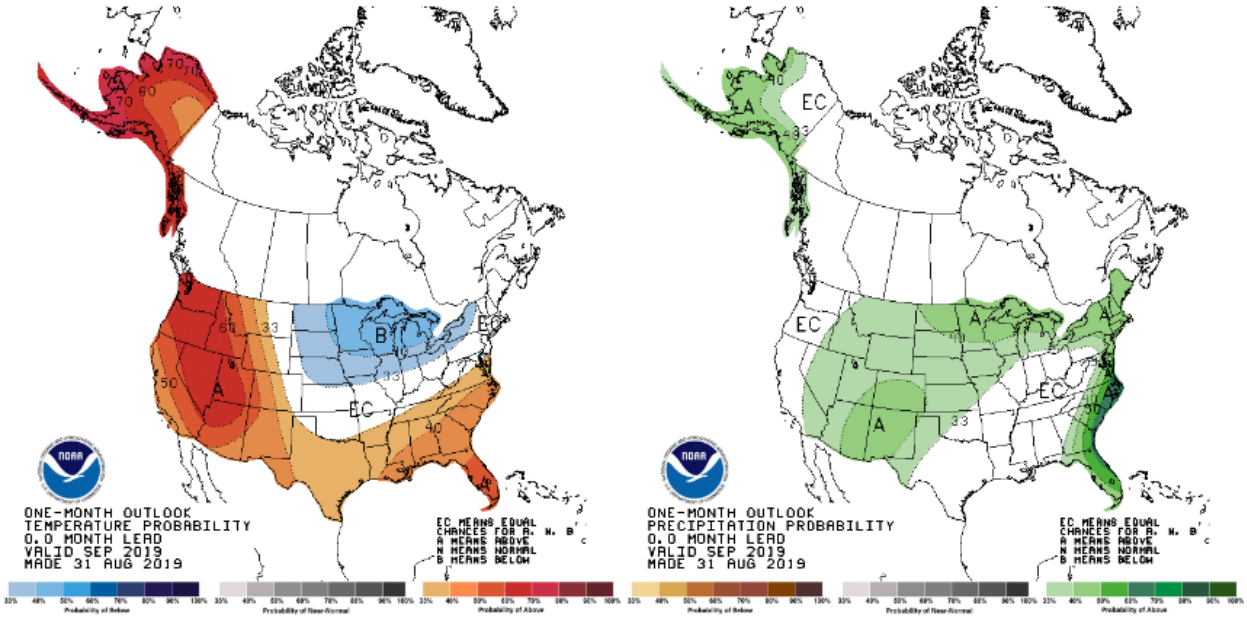


Figure 8. CPC September 2019 temperature and precipitation outlooks.

During the September-October-November 2019 period, the CPC outlooks in **Figure 9** are indicating increased chances for above-normal temperatures in most of the Missouri Basin. With regard to precipitation, the CPC indicates there is a small increase in chances for above-normal precipitation in the Missouri Basin, extending from Colorado into eastern Wyoming, eastern Montana, South Dakota and North Dakota.

During the December 2019-January-February 2020 period, CPC outlooks in **Figure 10** indicate a slight increase in chances for above-normal temperatures over western portions of the Missouri Basin. The precipitation outlook indicates increased chances for above-normal precipitation over most of the upper Missouri Basin.

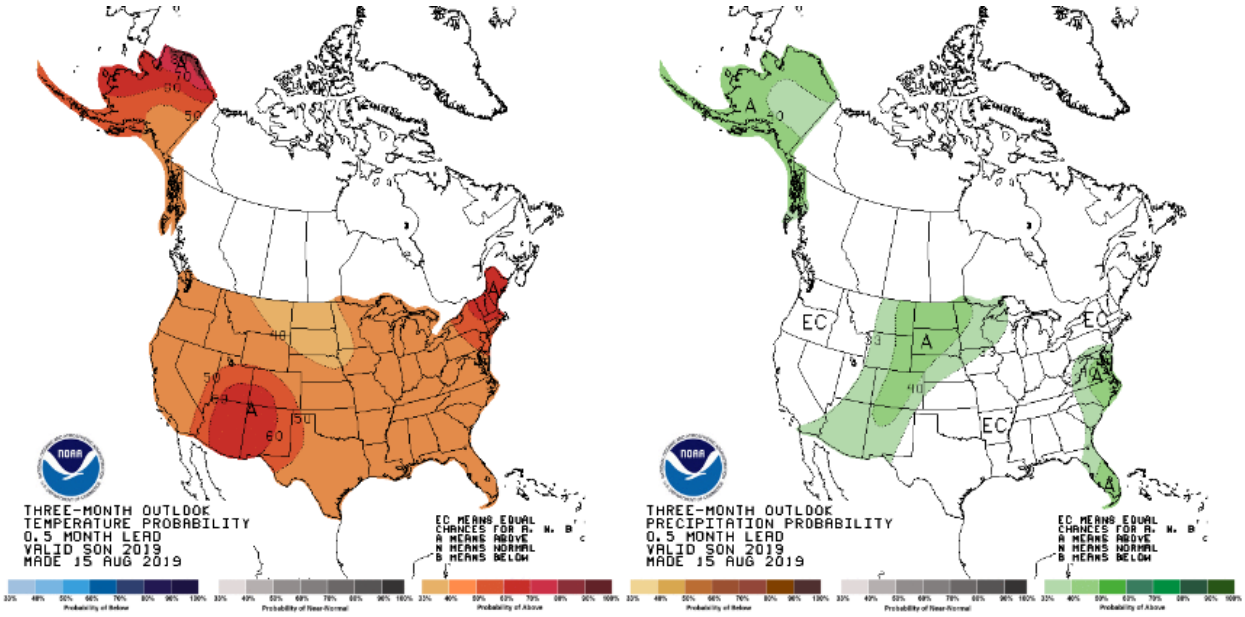


Figure 9. CPC September-October-November 2019 temperature and precipitation outlooks.

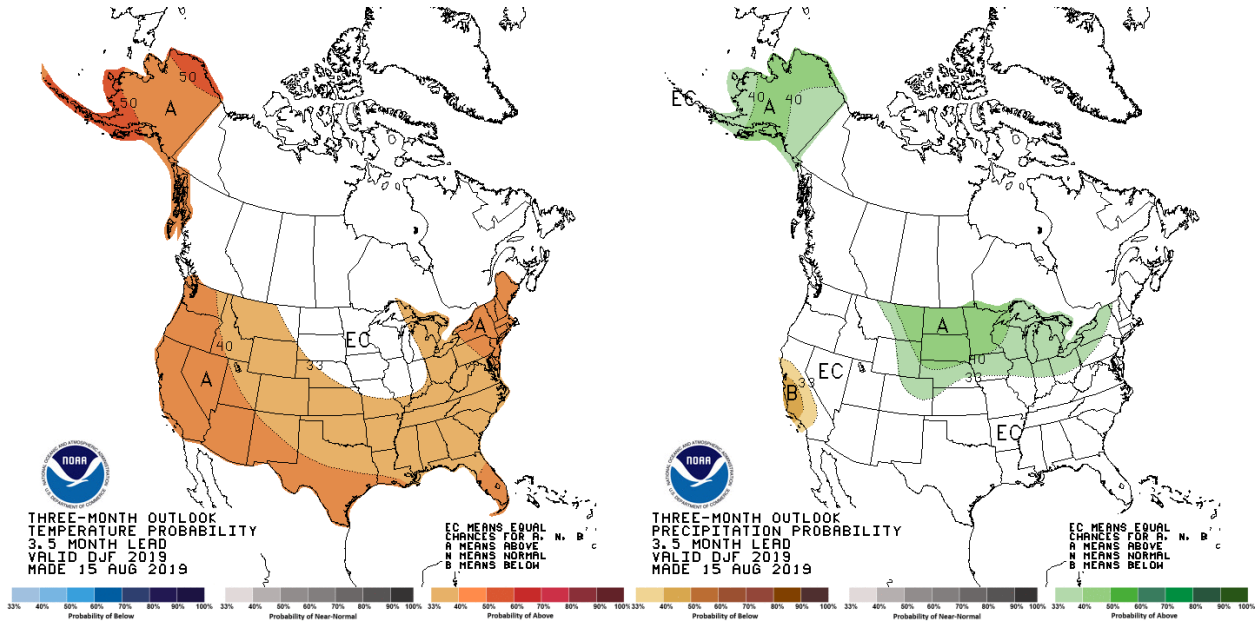


Figure 11. CPC December 2019-January-February 2020 temperature and precipitation outlooks.

Summary

The updated 2019 calendar year runoff forecast is **54.6 MAF, 215%** of average. Above-average runoff is forecast to occur throughout the upper Basin during the remainder of the year due to wet soil conditions and increased chances for precipitation.

Upper Missouri River Basin
October 2019 Calendar Year Runoff Forecast
October 4, 2019

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

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

September runoff in all reaches was much above average: Runoff from Gavins Point to Sioux City was more than 16 times the long-term average and more than twice the previous record, Gavins Point runoff was over 4 times average and almost twice the previous record, Fort Randall runoff was over 12 times average and set a new record, Oahe runoff was over 4 times average, Garrison runoff was over 2 times average and is the 2nd highest runoff of record, and Fort Peck was 1.5 times average. More significantly, accumulated runoff by August in the four lower reaches (Sioux City, Gavins Point, Fort Randall, and Oahe) was greater than the maximum January - December observed runoff in 121 years of record-keeping, with four months remaining in the calendar year. This new "mark" or "data point" gives you an idea of how wet the lower four reaches have been in 2019.

2019 Calendar Year Forecast Synopsis

The 2019 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA is **61.0 MAF, 241% of average**. The 2019 calendar year runoff forecast above Gavins Point Dam, which does not include runoff from the James, Vermillion and Big Sioux rivers, is **45.6 MAF, 198% of average**. The 2019 calendar year runoff forecast has exceeded the 1997 total runoff

volume of 49.0 MAF, which was the second highest runoff in 121 years of record-keeping. If realized, the forecast of 61.0 MAF would equal the previous record runoff established in 2011.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next three months, expected inflow could range from the **63.3 MAF** upper basic forecast to the **59.3 MAF** lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that three months are being forecast for this October 1 forecast (9 months observed/3 months forecast), the range of possible wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is attributed to all six reaches for the entire year, particularly as it relates to summer and fall precipitation. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for October 1, 2019 is shown in **Figure 1**. The drought monitor is available at http://droughtmonitor.unl.edu/. The Drought Monitor shows no Abnormal Dryness (D0) conditions or drought conditions (D1 – D4) present anywhere in the Basin.

The Seasonal Drought Outlook in **Figure 2**, which extends through the end of December, indicates no changes to drought conditions in the Missouri Basin during the forecast period.

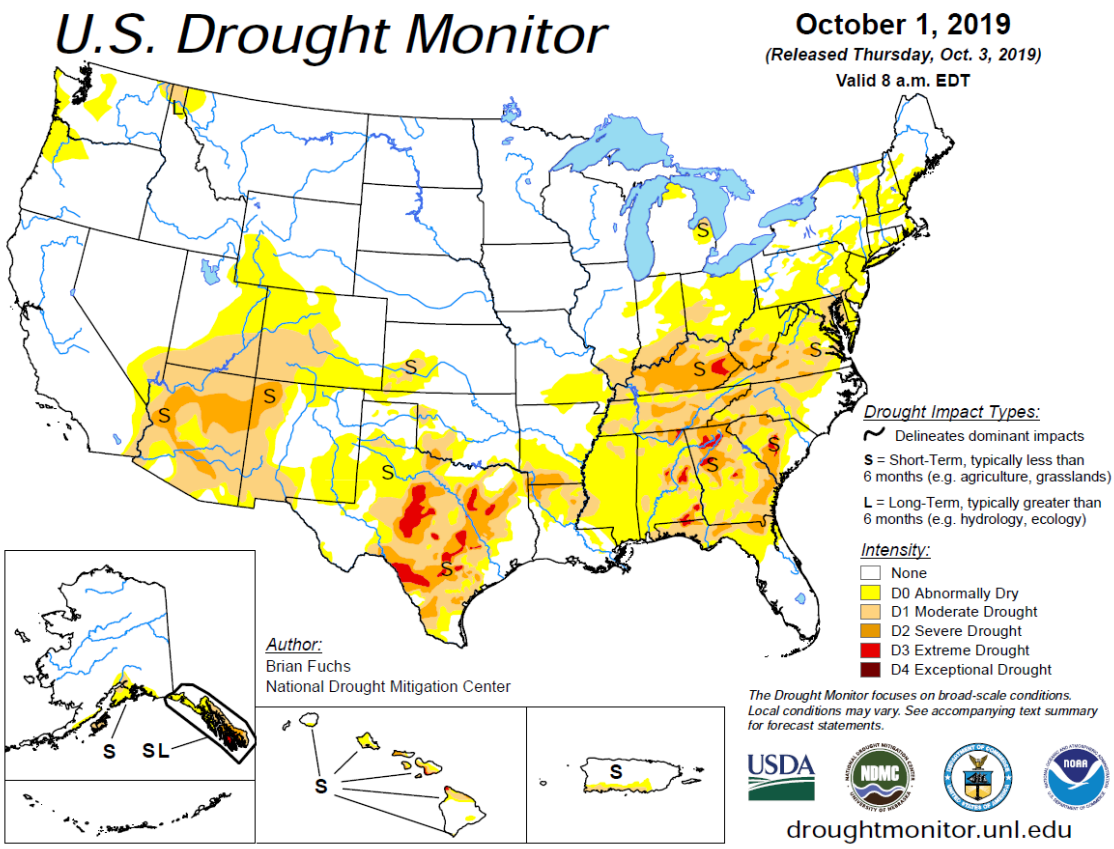


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for October 1, 2019.

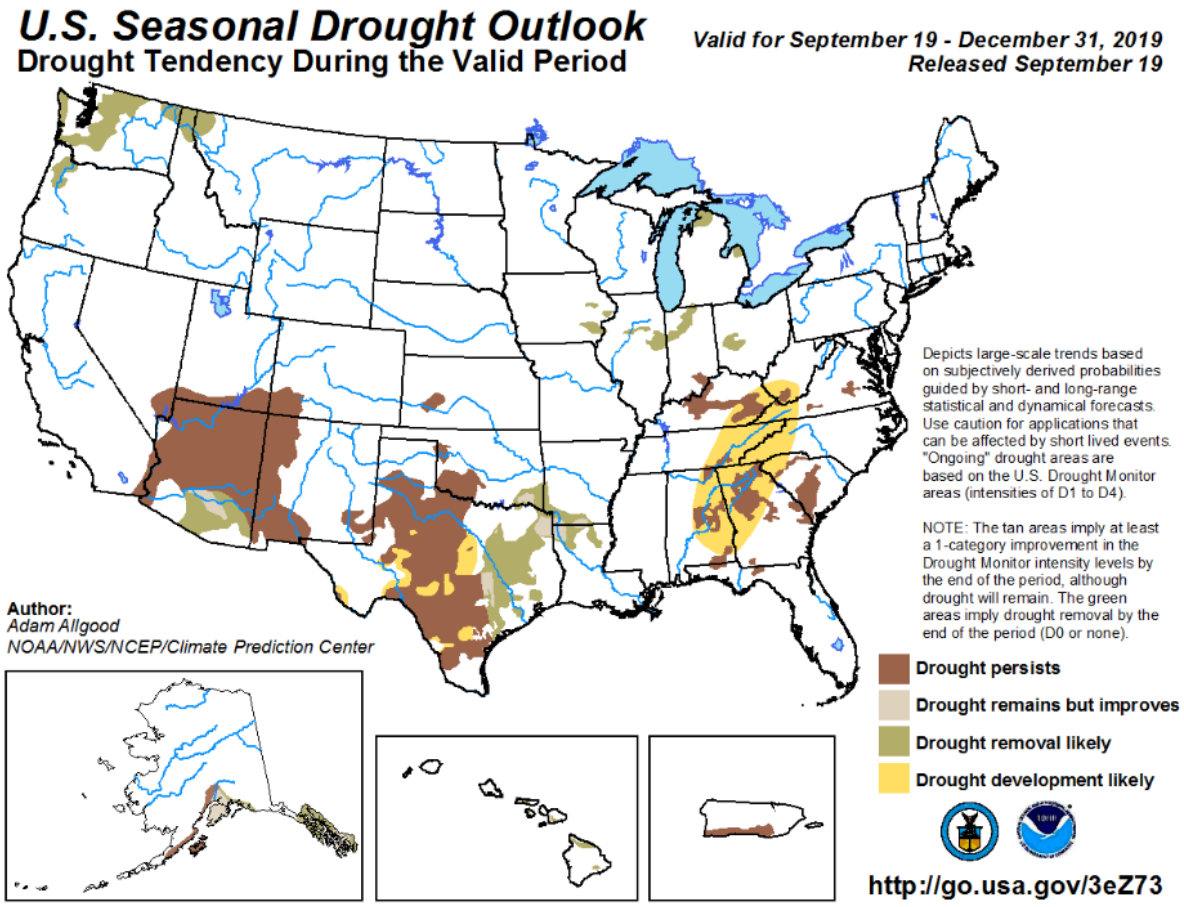


Figure 2. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. Precipitation as a percent of normal in September is shown in the top image of **Figure 3**, and July-August-September precipitation as a percent of normal is shown in the bottom image of **Figure 3**. September precipitation was greater than 400% of normal in eastern Montana and western North Dakota, while it was greater than 200% of normal in eastern North Dakota, much of South Dakota and northcentral Nebraska. The very high September precipitation resulted in record high runoff volumes in the Sioux City, Gavins Point, and Fort Randall reaches, as well as high river flows in the Platte River, the lower Kansas River, and the lower Missouri River. The three-month precipitation as a percent of normal image shows that precipitation was well-above normal throughout most of the upper Basin.

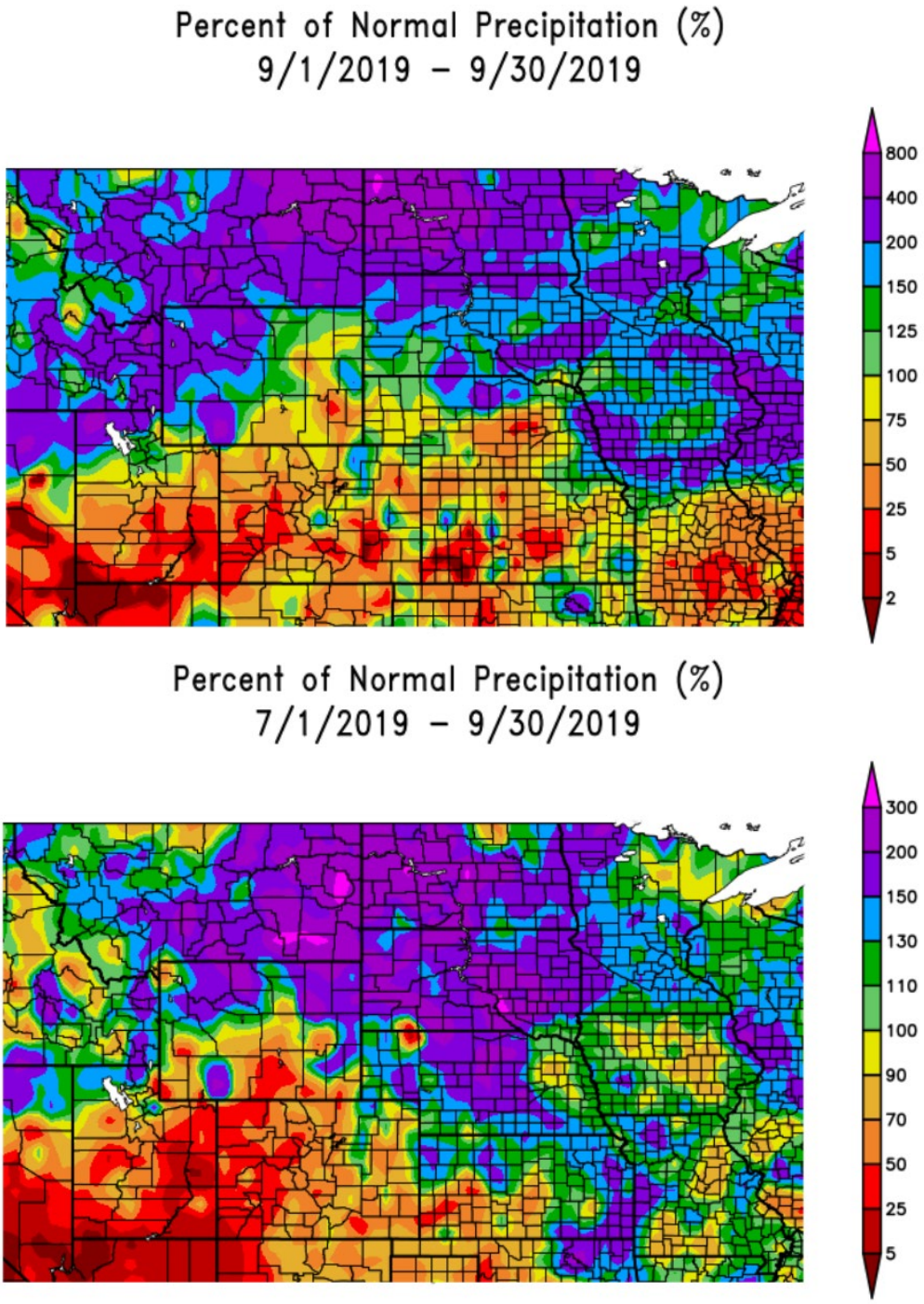


Figure 3. September 2019 and July-August-September 2019 Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature departures for September are shown in degrees Fahrenheit (deg F) in the top image of **Figure 4**. September temperatures ranged from about normal in Montana and North Dakota, to 6-8 deg F above normal in Nebraska, Kansas, and Missouri. July-August-September temperature departures, shown in the bottom image of **Figure 4,** show an about normal temperature pattern that has impacted much of the Missouri Basin during late summer and early

fall. In most of the upper Basin, departures ranged from 2 deg F below normal to 2 deg F above normal.

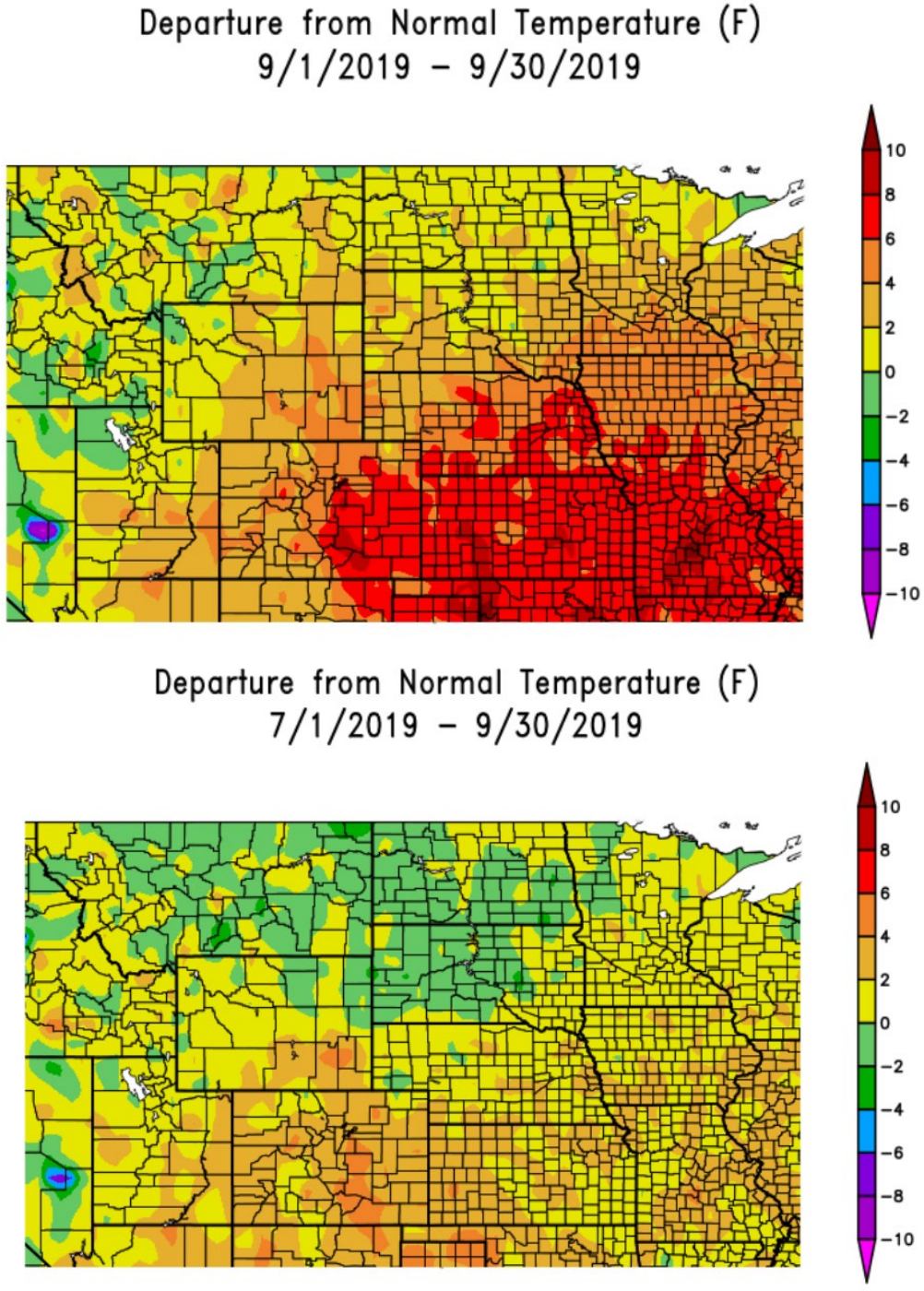


Figure 4. September 2019 and July-August-September 2019 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 5 shows the September 29, 2019 NOAA NLDAS ensemble soil moisture anomalies and soil moisture percentiles. Based on the NLDAS soil moisture anomaly map, soil moisture anomalies are well above normal everywhere in the Basin except Colorado. In terms of percentile, total soil moisture exceeds the 98th percentile, which is very wet, in parts of eastern Montana, western North Dakota, South Dakota, and northern Nebraska. Consequently, these areas will be susceptible to above-average runoff and flooding if intense rainfall occurs.

Figure 6 shows the September 30, 2019 NOAA CPC soil moisture anomalies and soil moisture percentiles. The CPC maps agree with the NLDAS maps, showing very wet soils everywhere in the Basin except Colorado.

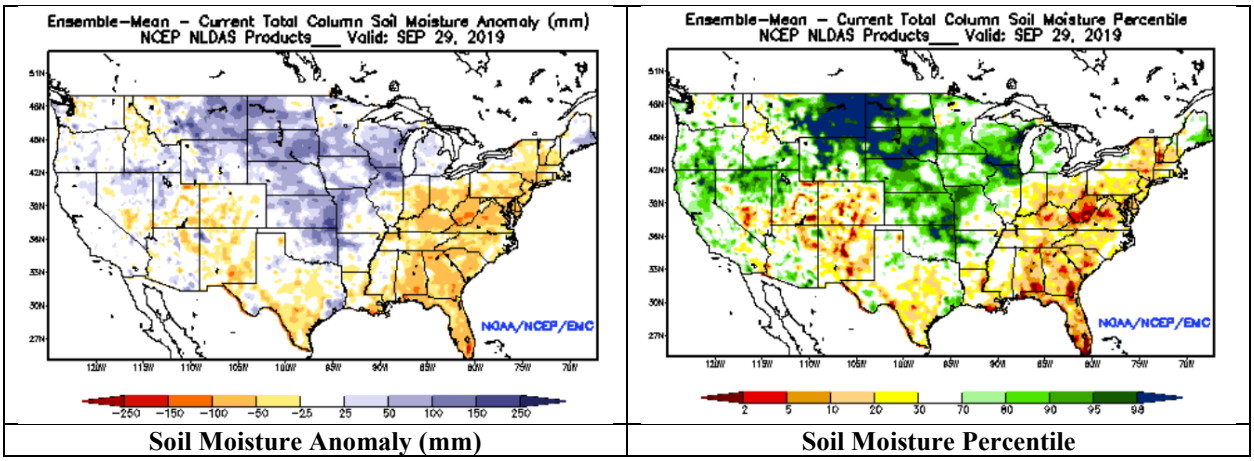


Figure 5. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

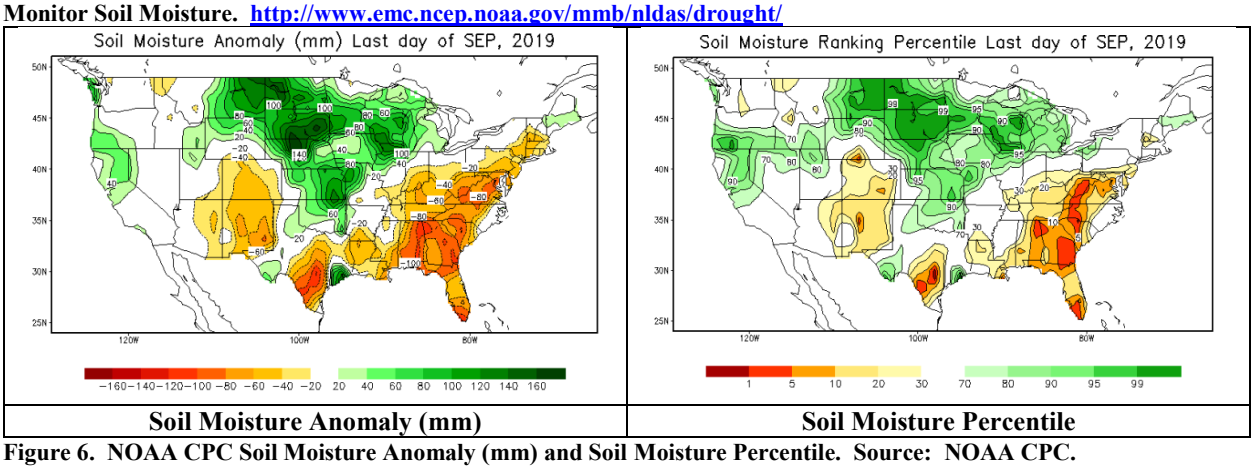


Figure 6. NOAA CPC Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA CPC. https://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The CPC's September 30, 2019 ENSO Outlook indicates that ENSO-neutral conditions are present. Equatorial sea surface temperatures are above average across the western Pacific Ocean, and below average across the eastern Pacific Ocean. ENSO-neutral conditions are favored for fall, continuing into spring 2020 with a 55-60% chance.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

With regard to future weather, the CPC temperature outlook for October 9-13 (**Figure 7, left**) is indicating increased chances for below-normal temperatures over the entire Missouri Basin. Regarding precipitation (**Figure 7, right**), the CPC is indicating increased chances for above-normal precipitation in Montana and western North Dakota, and increased chances for below-normal precipitation in southeastern North Dakota, South Dakota, northern Nebraska, and northern Iowa.

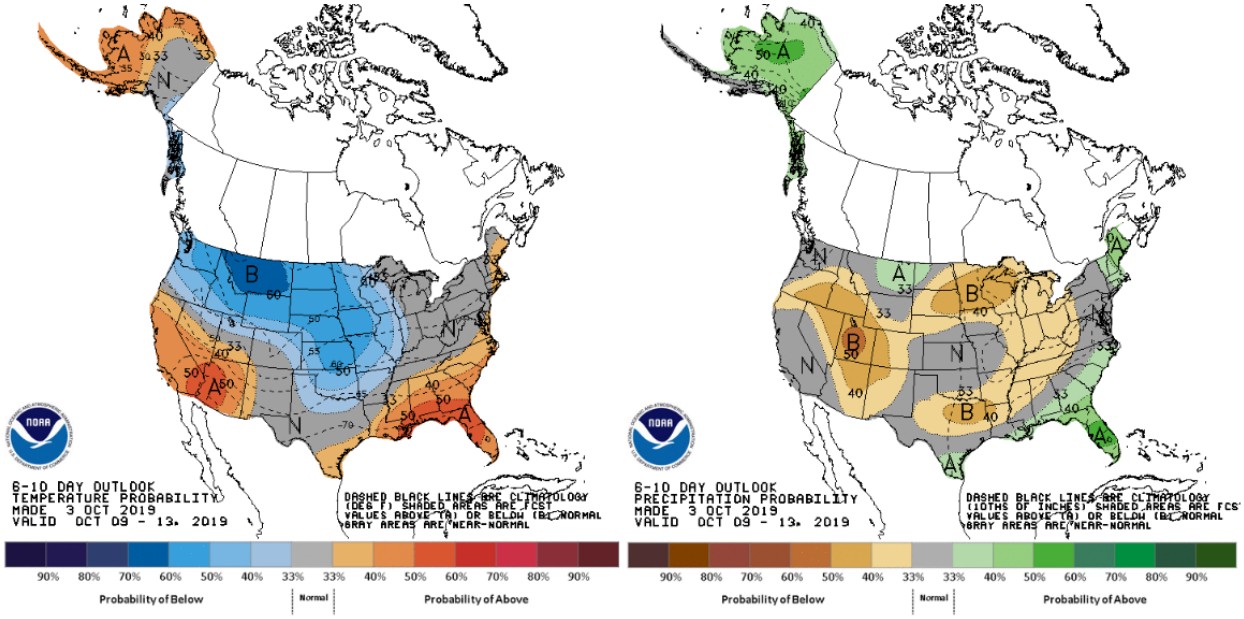


Figure 7. CPC 6-10 Day temperature and precipitation outlooks for October 9-13, 2019.

The October CPC outlooks in **Figure 8** indicate increased chances for below-normal temperatures over the north-central U.S., including much of the Dakotas and Montana. With regard to precipitation, the CPC is indicating increased chances for above-normal precipitation over the entire Missouri Basin.

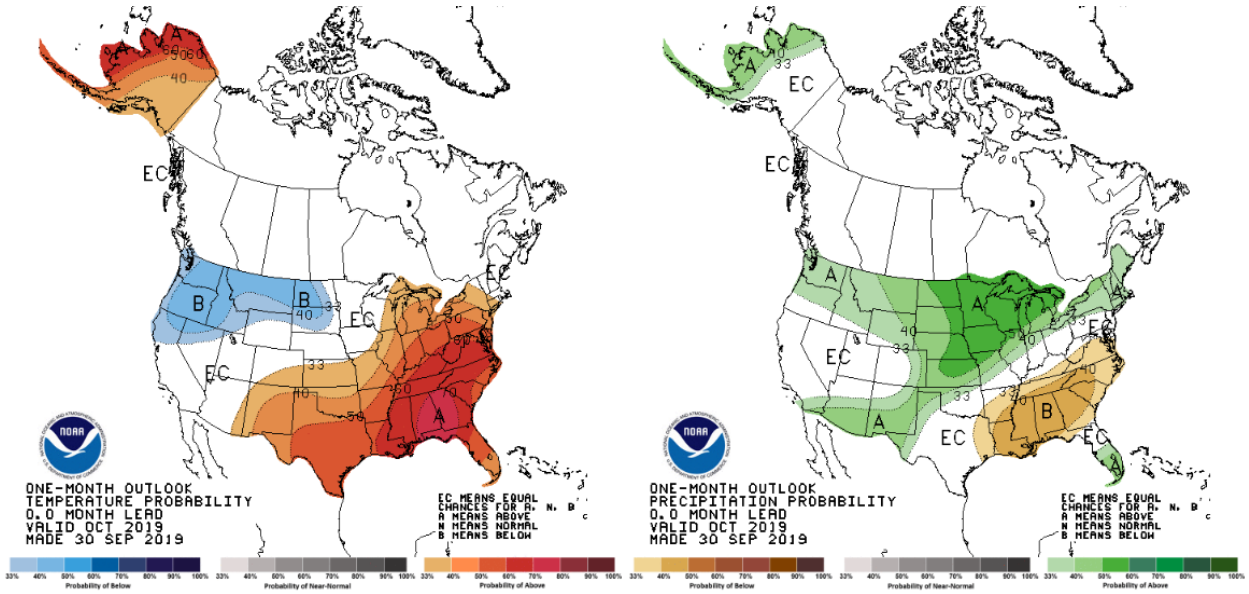


Figure 8. CPC October 2019 temperature and precipitation outlooks.

During the October-November-December 2019 period, the CPC outlooks in **Figure 9** are indicating increased chances for above-normal temperatures across the Missouri Basin. With regard to precipitation, the CPC indicates there is an increase in chances for above-normal precipitation over most of the Missouri Basin.

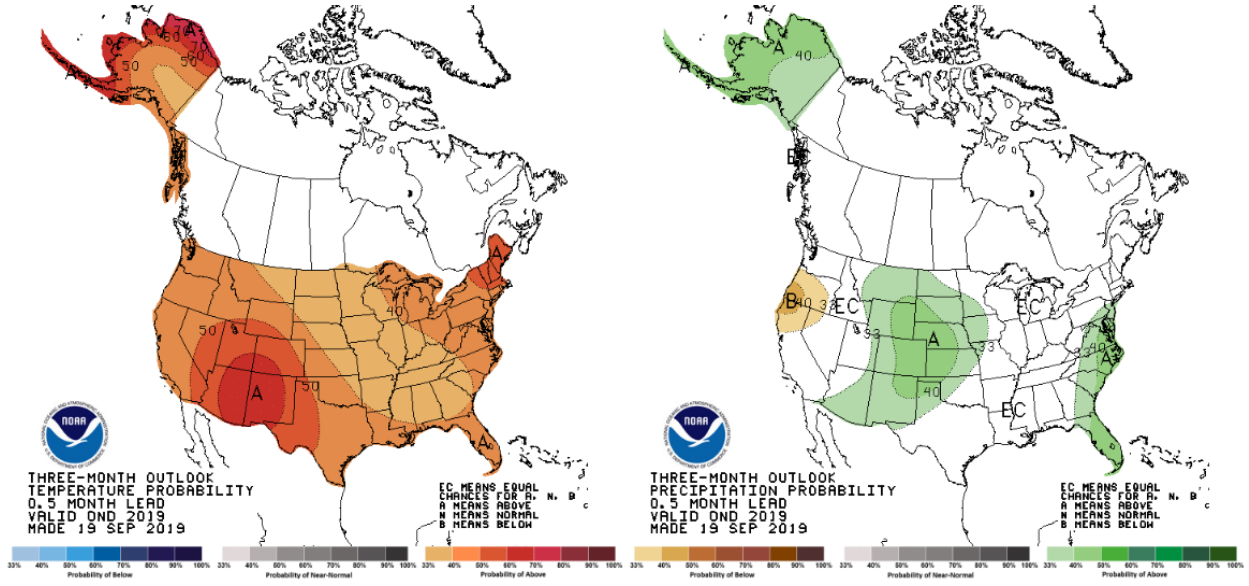


Figure 9. CPC October-November-December 2019 temperature and precipitation outlooks.

Summary

The updated 2019 calendar year runoff forecast is **61.0 MAF, 241%** of average. Above-average runoff is forecast to occur throughout the upper Basin during the remainder of the year due to wet soil conditions and increased chances for precipitation.

Upper Missouri River Basin
November 2019 Calendar Year Runoff Forecast
November 7, 2019

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

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

October runoff in the upper Basin above Sioux City was 3.2 MAF, tying the previous record October runoff (in 1923). Well-above average October runoff is primarily a result of above-normal fall precipitation, particularly in northeastern Montana and central North Dakota. October runoff was also influenced by above-normal precipitation in North Dakota and northern South Dakota, primarily from the early October snowstorm that brought several feet of accumulated snow to these areas. Melting snow caused a significant boost in inflows to Oahe, finishing the month with over 6 times the average October runoff. October runoff in the Gavins Point reach was almost 3 times the average, ranking 1st among Octobers; and, October runoff in the Gavins Point to Sioux City reach was more than 10 times the average runoff, also ranking 1st among Octobers.

2019 Calendar Year Forecast Synopsis

The 2019 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA is **60.2 MAF, 238%** of average. Accumulated runoff as of November 1, 2019 was 56.7 MAF. 2019 runoff is currently the second highest runoff in 121 years of record-keeping. The 2019 forecast would nearly equal the previous record runoff from 2011, which was 61 MAF. The 2019

calendar year forecast is bracketed by the upper basic forecast (wetter than expected) of 61.2 MAF and the lower basic forecast (drier than expected) of 59.4 MAF. The difference in the upper basic and lower basic forecasts reflects the range of possible runoff we could see over the next 2 months.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for October 29, 2019 is shown in **Figure 1**. The drought monitor is available at http://droughtmonitor.unl.edu/. The Drought Monitor shows no Abnormal Dryness (D0) conditions or drought conditions (D1 – D4) present anywhere in the upper Missouri Basin.

The Seasonal Drought Outlook in **Figure 2**, which extends through the end of December, indicates no changes to drought conditions in the Missouri Basin during the forecast period.

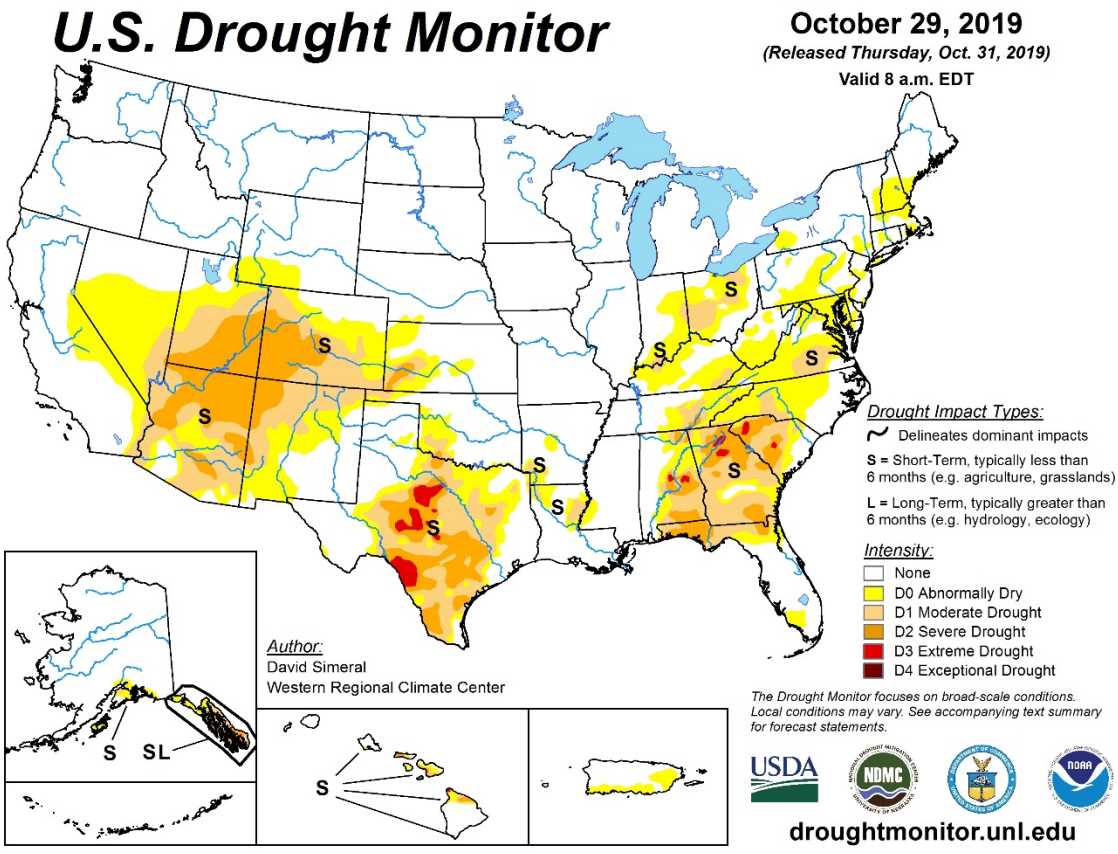


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for October 29, 2019.

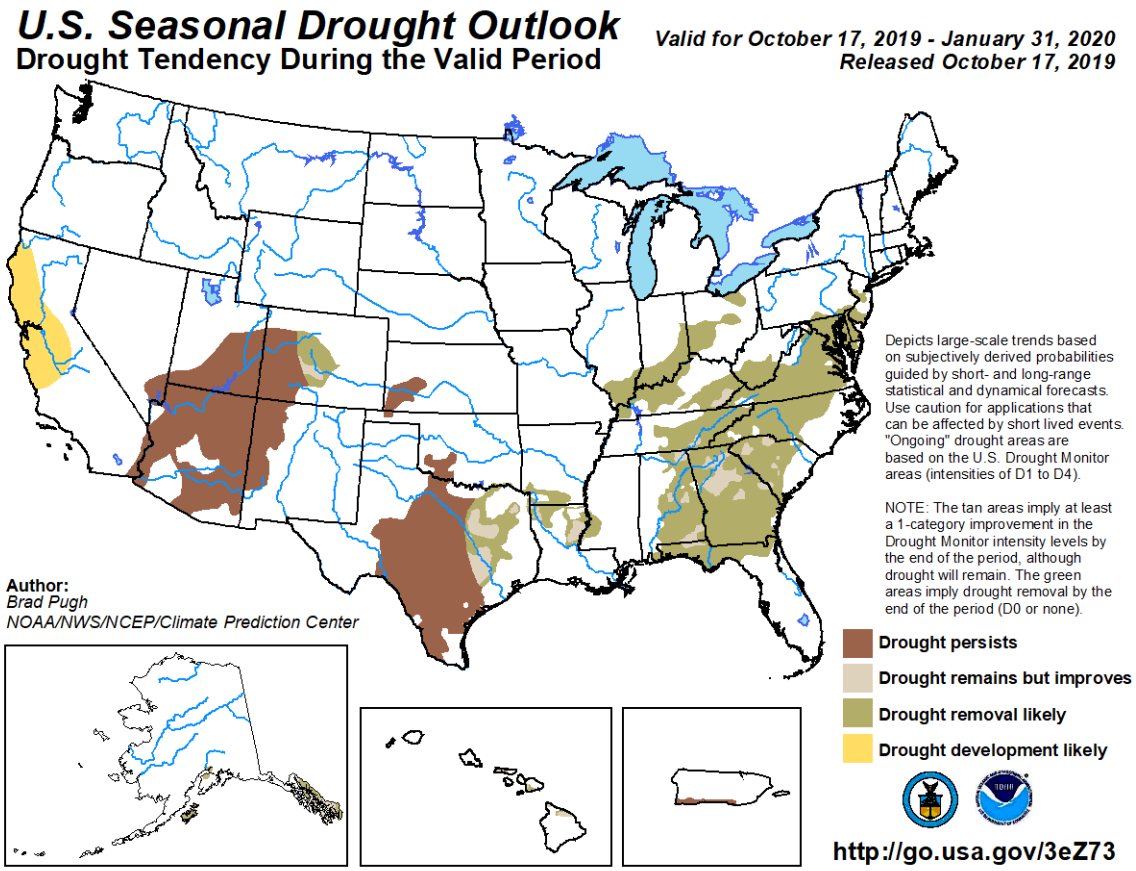


Figure 2. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. Precipitation as a percent of normal in October is shown in the top image of **Figure 3**, and August-September-October precipitation as a percent of normal is shown in the bottom image of **Figure 3**. October precipitation was greater than 150% 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 October 10-12. A second potent storm produced heavy rainfall October 20 and 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 contribute to Oahe Reservoir inflows. Two-day rainfall totals measured by rain gage include 2.11 inches at Mobridge, SD, 1.45 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 greater than normal, and 17 inches of snowfall. It also received 17 inches of snowfall in October, 14.9 inches greater than normal.

The three-month precipitation as a percent of normal image shows that precipitation was greater than 150% of normal throughout most of the upper Basin. Some areas of northeastern Montana, and northwestern North Dakota received two to three times the normal August-September-

October precipitation. This heavy precipitation over the past three months is the reason why the upper Missouri Basin received three times the average amount of runoff during the August-September-October period.

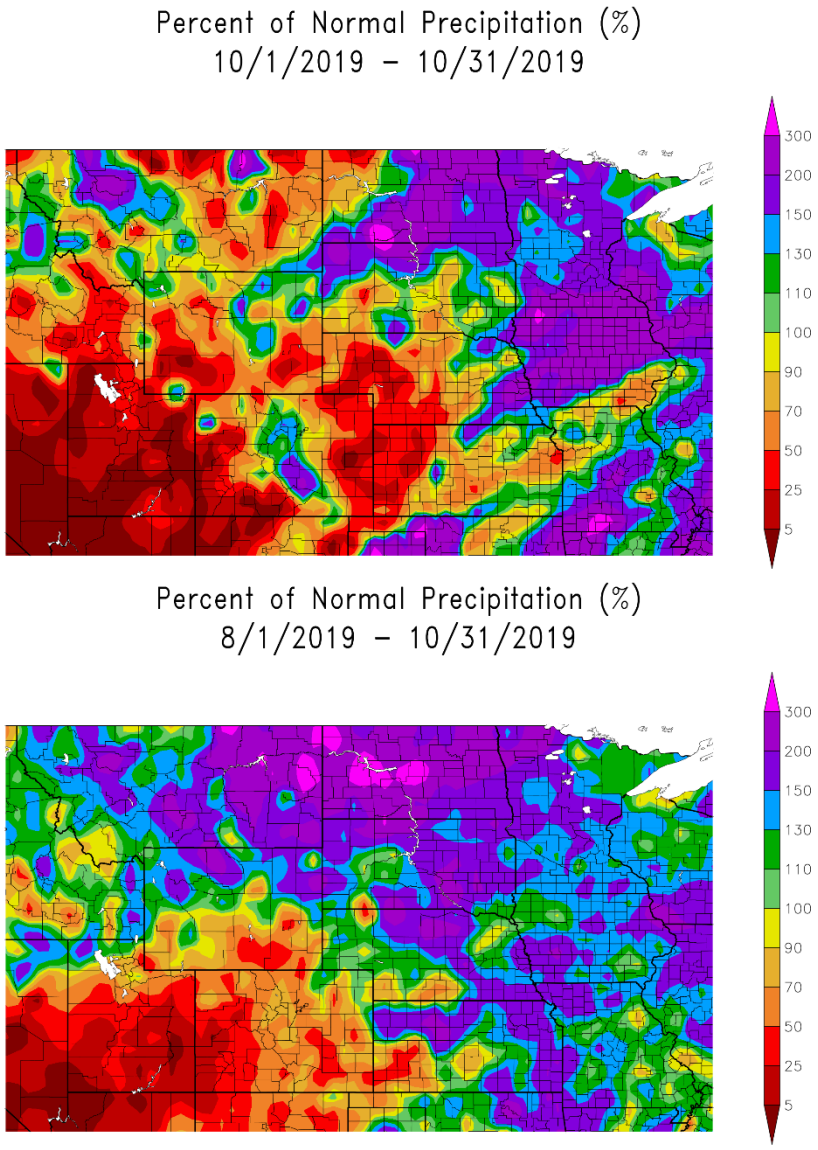


Figure 3. October 2019 and August-September-October 2019 Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature departures for October are shown in degrees Fahrenheit (deg F) in the top image of **Figure 4**. October temperatures ranged from 6 to over 9 deg F below normal in Montana, Wyoming, North Dakota, South Dakota and western Nebraska. Temperatures were 3 deg F below normal in most other areas of the upper Basin. August-September-October temperature departures, shown in the bottom image of **Figure 4,** show a below-normal normal temperature pattern that has impacted much of the Missouri Basin during late summer and early fall**.** In most of the upper Basin, departures ranged from 2 to 4 deg F below normal.

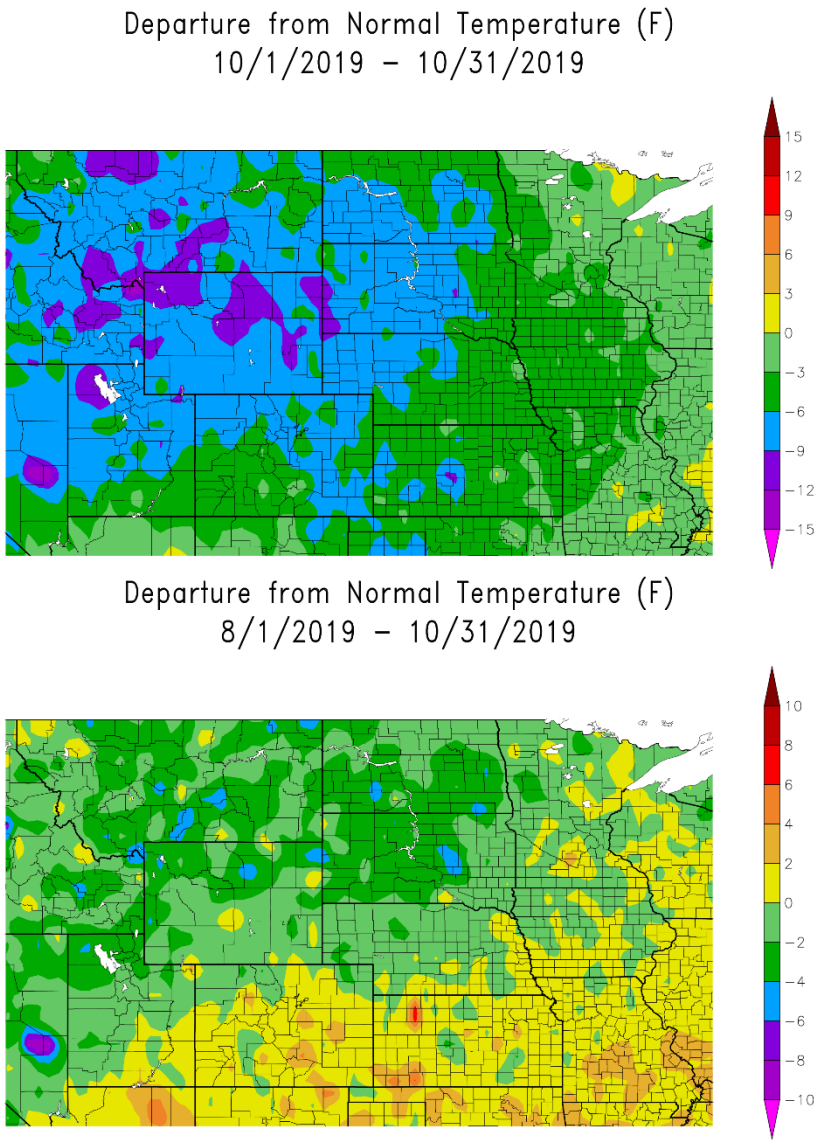


Figure 4. October 2019 and August-September-October 2019 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 5 shows the November 1, 2019 NOAA NLDAS ensemble soil moisture anomalies and soil moisture percentiles. Based on the NLDAS soil moisture anomaly map, soil moisture anomalies are well above normal everywhere in the Basin except Colorado. In terms of percentile, total soil moisture exceeds the 98th percentile, which is very wet, in much of Montana,

western North Dakota, and South Dakota. Consequently, these areas will be susceptible to above-average runoff and flooding if intense rainfall occurs.

Figure 6 shows the October 31, 2019 NOAA CPC soil moisture anomalies and soil moisture percentiles. The CPC maps agree with the NLDAS maps, showing very wet soils, exceeding the 99th percentile, everywhere in the Basin except Colorado.

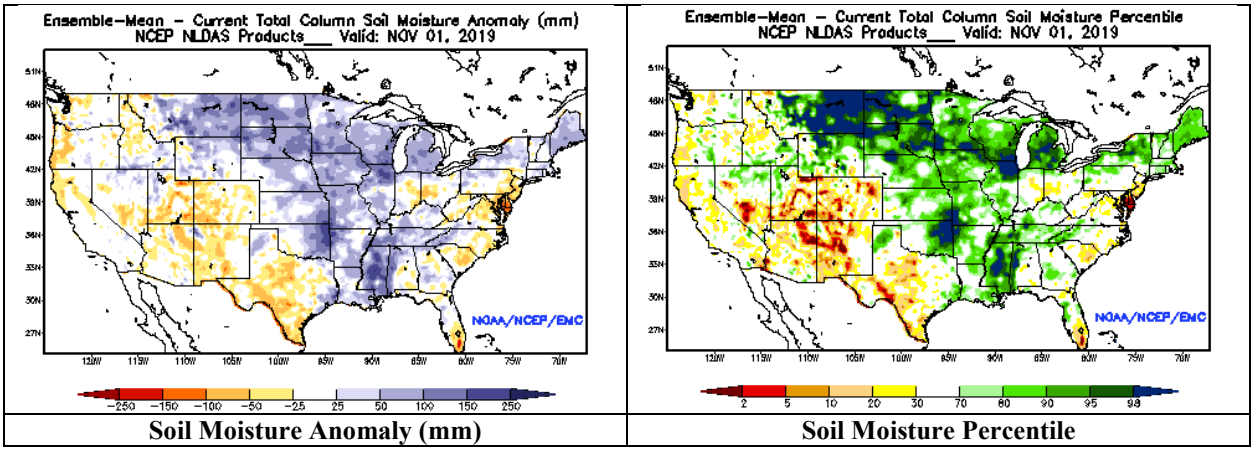


Figure 5. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

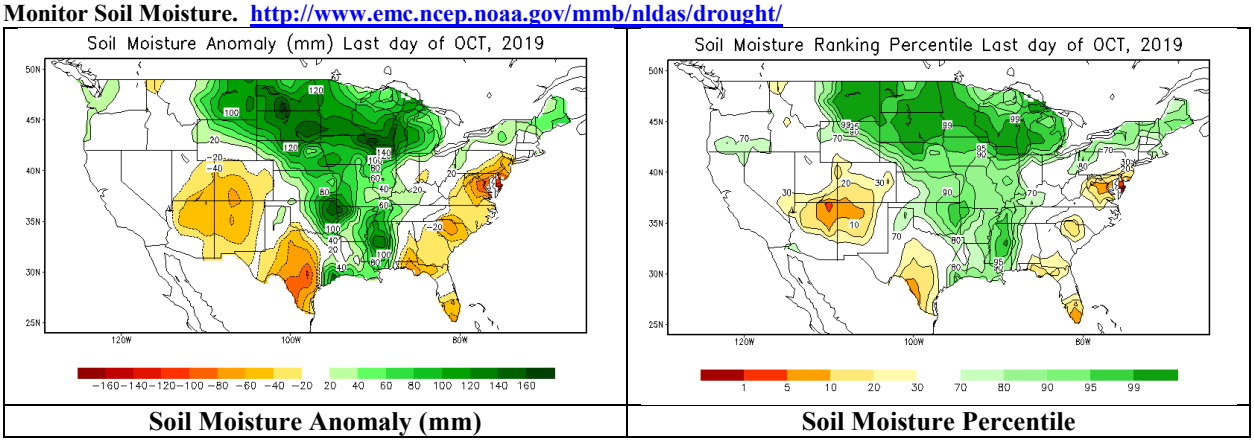


Figure 6. NOAA CPC Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA CPC. https://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml

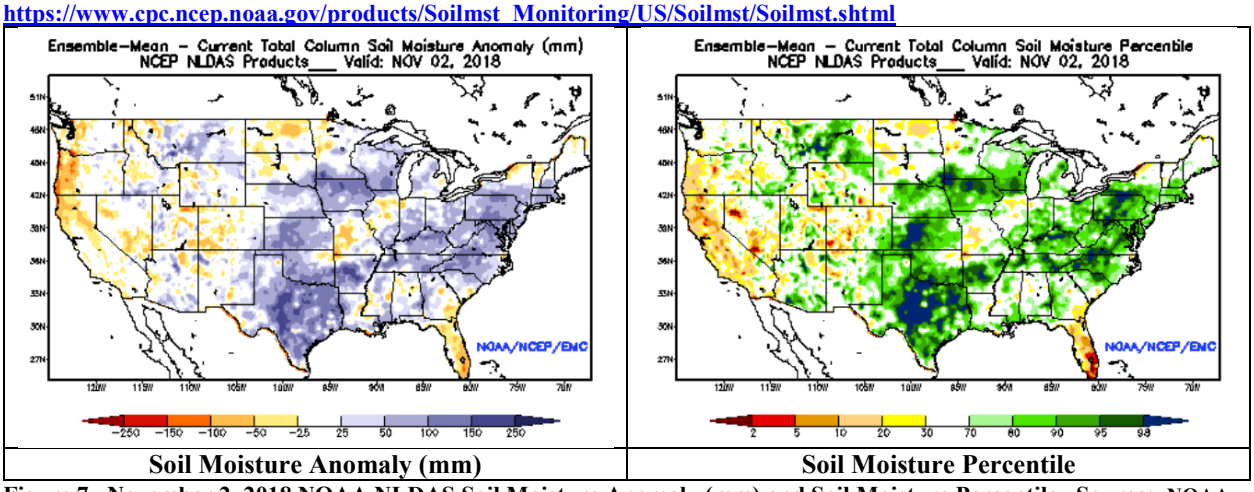


Figure 7. November 2, 2018 NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

For comparison, the November 2, 2018 NOAA NLDAS soil moisture anomaly and soil moisture percentile maps are shown in **Figure 7**. Soil moisture on November 2 was wetter-than-normal in Montana, northern Nebraska, southeastern South Dakota, and much of Iowa. Wetter-than-normal percentiles primarily ranged from the 70th to the 90th percentile, with some isolated wet areas ranging from the 95th to 98th percentile. By comparison, 2019 soil moisture is much wetter than 2018, and over basin-wide areas compared to isolated areas in 2018.

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The CPC's November 4, 2019 ENSO Outlook indicates that ENSO-neutral conditions are present. Equatorial sea surface temperatures are above average across the western Pacific Ocean, and below average across the eastern Pacific Ocean. ENSO-neutral conditions are favored for the fall season, continuing into spring 2020 with a 55-60% chance.

Winter Weather Outlook

The CPC issued its Winter Outlook on October 17 focusing on future climate conditions from December 2019 to February 2020. Within the Missouri Basin, the CPC is indicating equal chances for temperatures in the north central U.S. with a slight tilt toward warmer-than-normal temperatures in Montana and Wyoming. With regard to precipitation, wetter conditions are likely in the upper Basin with the greatest increase in precipitation chances extending from central Montana across southern North Dakota and South Dakota.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

With regard to future weather, the CPC temperature outlook for November 13-19 (**Figure 8, left**) is indicating increased chances for below-normal temperatures over most of the Missouri Basin, particularly in the lower Basin. In the Rocky Mountains, there is an increased chanced for above-normal temperatures. Regarding precipitation (**Figure 8, right**), the CPC is indicating a slight increase in the chances for above-normal precipitation in the upper Basin plains, and below-normal chances elsewhere.

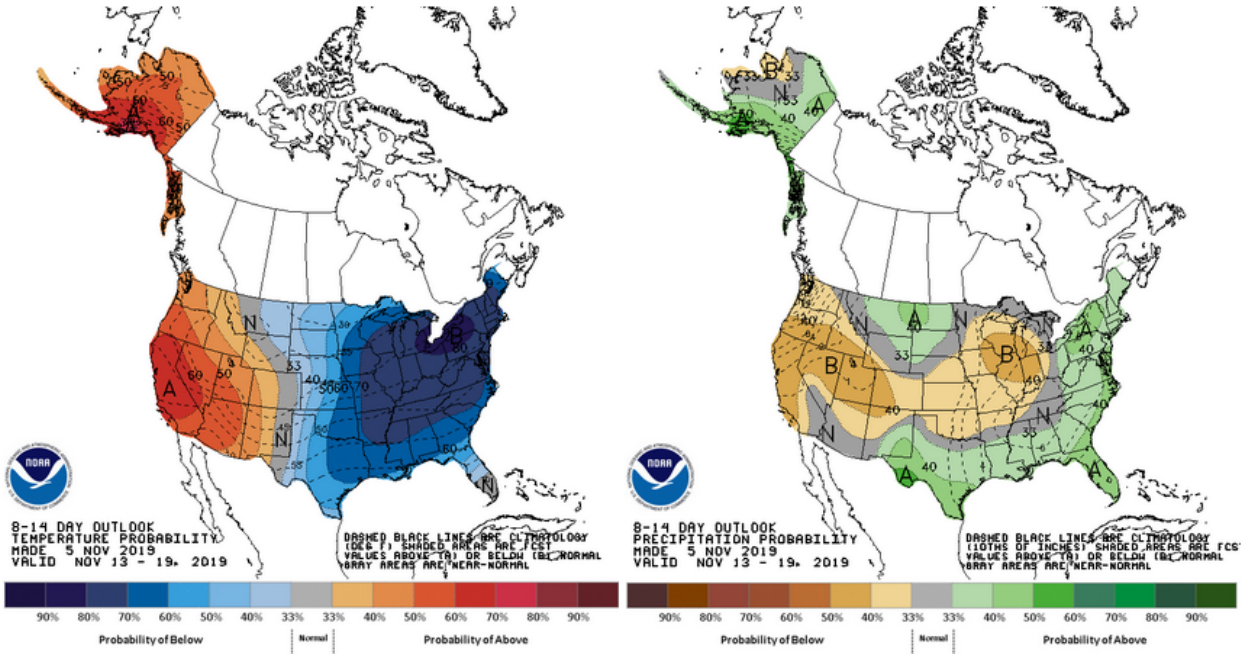


Figure 8. CPC 8-14 Day temperature and precipitation outlooks for November 13-19, 2019.

The November CPC outlooks in **Figure 9** indicate increased chances for below-normal temperatures over the Dakotas, and some areas of the lower Basin; equal chances for temperatures in Nebraska, Montana and Wyoming, and a slight tilt toward above-normal temperatures in the Rocky Mountains. With regard to precipitation, the CPC is indicating increased chances for above-normal precipitation over Montana, and equal chances in the remainder of the upper Basin. There is an increased chance for below-normal precipitation in eastern Kansas, southern Iowa, and Missouri.

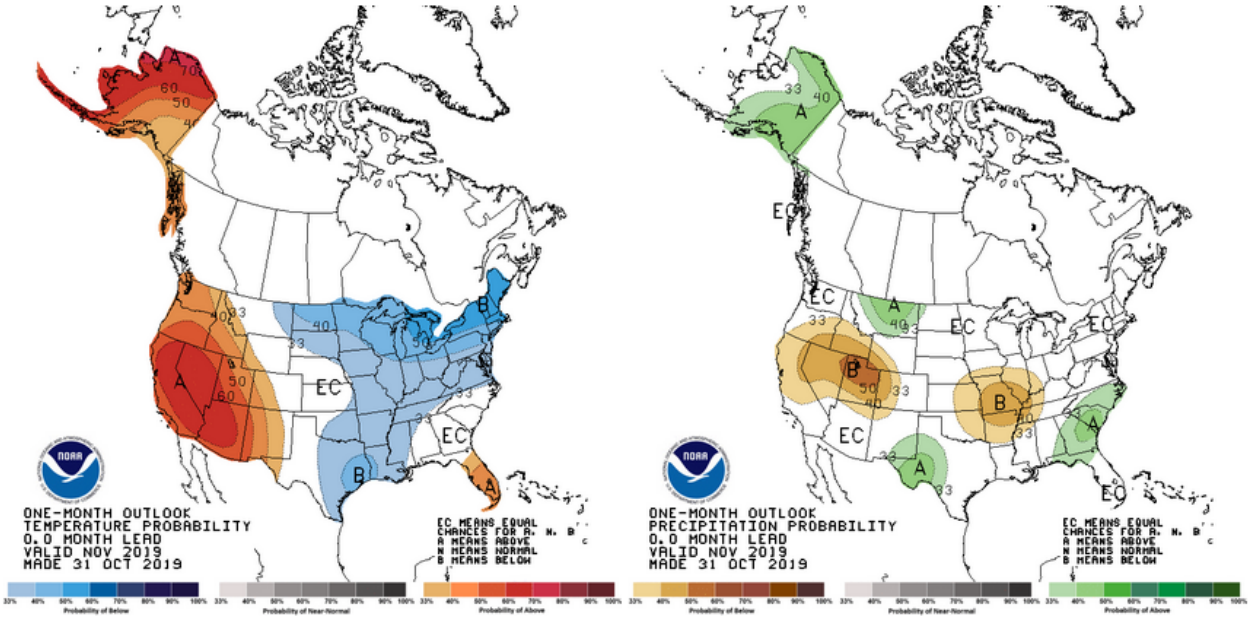


Figure 9. CPC November 2019 temperature and precipitation outlooks.

During the November-December 2019-January 2020 period, the CPC outlooks in **Figure 10** are indicating increased chances for above-normal temperatures across the Missouri Basin. With regard to precipitation, the CPC indicates there is an increased chance for above-normal precipitation over the Missouri Basin. These outlooks, though preceding the winter weather outlook by one month, align closely with the CPC winter weather outlook.

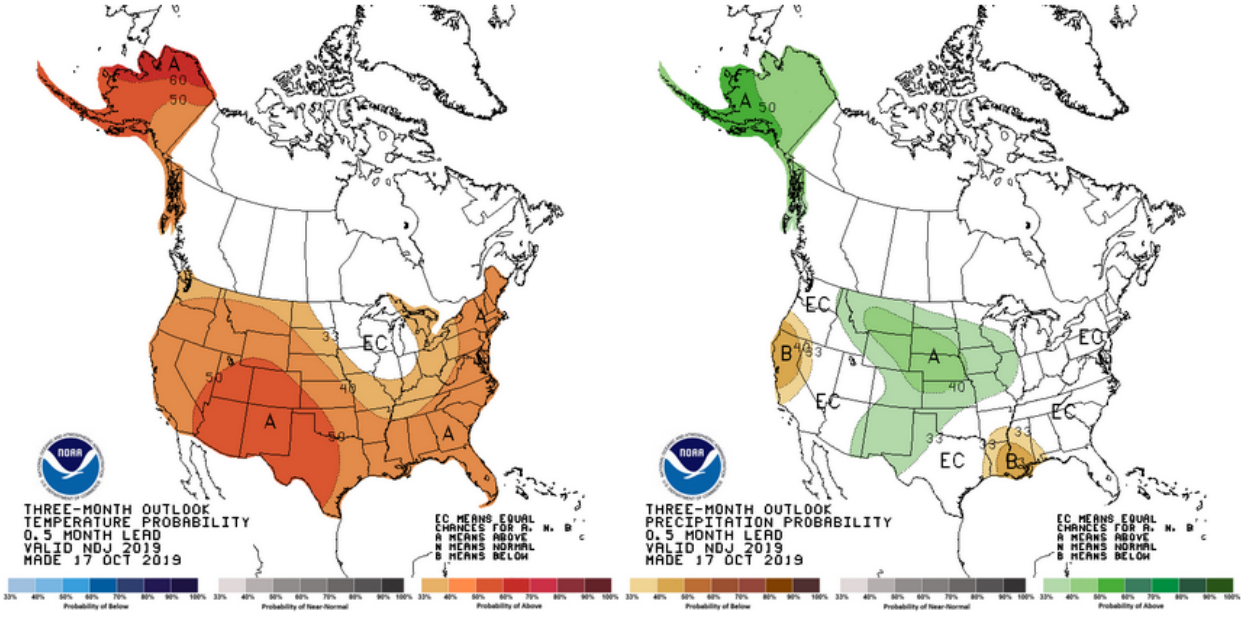


Figure 10. CPC November-December 2019-January temperature and precipitation outlooks.

Summary

The updated 2019 calendar year runoff forecast is **60.2 MAF**, **238% of average**. Runoff will very likely be above-average in November and December given the current above-average streamflow in the Basin. Future temperatures will influence the timing of river ice formation, and the volume of runoff received in December: colder-than-normal temperatures could reduce December runoff, but it is more likely that warmer temperatures could delay river ice formation, resulting in above-average December runoff.

Upper Missouri River Basin
December 2019 Calendar Year Runoff Forecast
December 5, 2019

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

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

November runoff in the upper Basin above Sioux City was 2.0 MAF, almost twice the average, continuing the trend of well-above-average runoff observed in the Basin since March. November runoff is primarily a result of above-normal fall precipitation and snowmelt in some areas. November runoff was above average in all reaches except the Fort Randall reach.

2019 Calendar Year Forecast Synopsis

The 2019 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA is **60.4 MAF, 238%** of average. Accumulated runoff as of December 1, 2019 was 58.8 MAF. 2019 runoff is currently the second highest runoff in 121 years of record-keeping. The 2019 forecast would nearly equal the previous record runoff from 2011, which was 61.0 MAF. The 2019 calendar year forecast is bracketed by the upper basic forecast (wetter than expected) of 60.8 MAF and the lower basic forecast (drier than expected) of 60.0 MAF. The difference in the upper basic and lower basic forecasts reflects the range of possible runoff we could see over the next month.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for November 26, 2019 is shown in **Figure 1**. The drought monitor is available at http://droughtmonitor.unl.edu/. The Drought Monitor shows no Abnormal Dryness (D0) conditions or drought conditions (D1 – D4) present anywhere in the upper Missouri Basin.

The Seasonal Drought Outlook in **Figure 2**, which extends through the end of February, indicates no changes to drought conditions in the Missouri Basin during the forecast period.

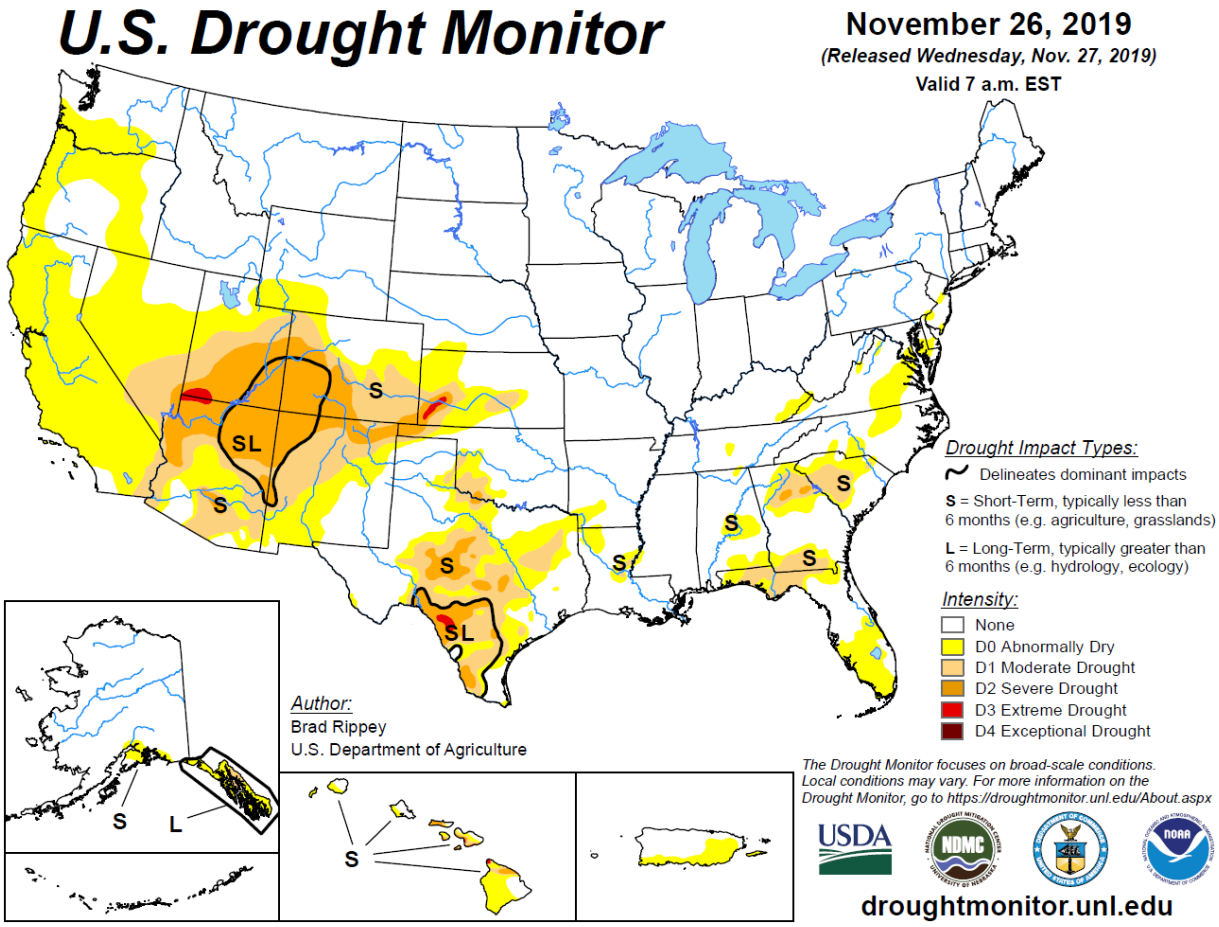


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for November 26, 2019.

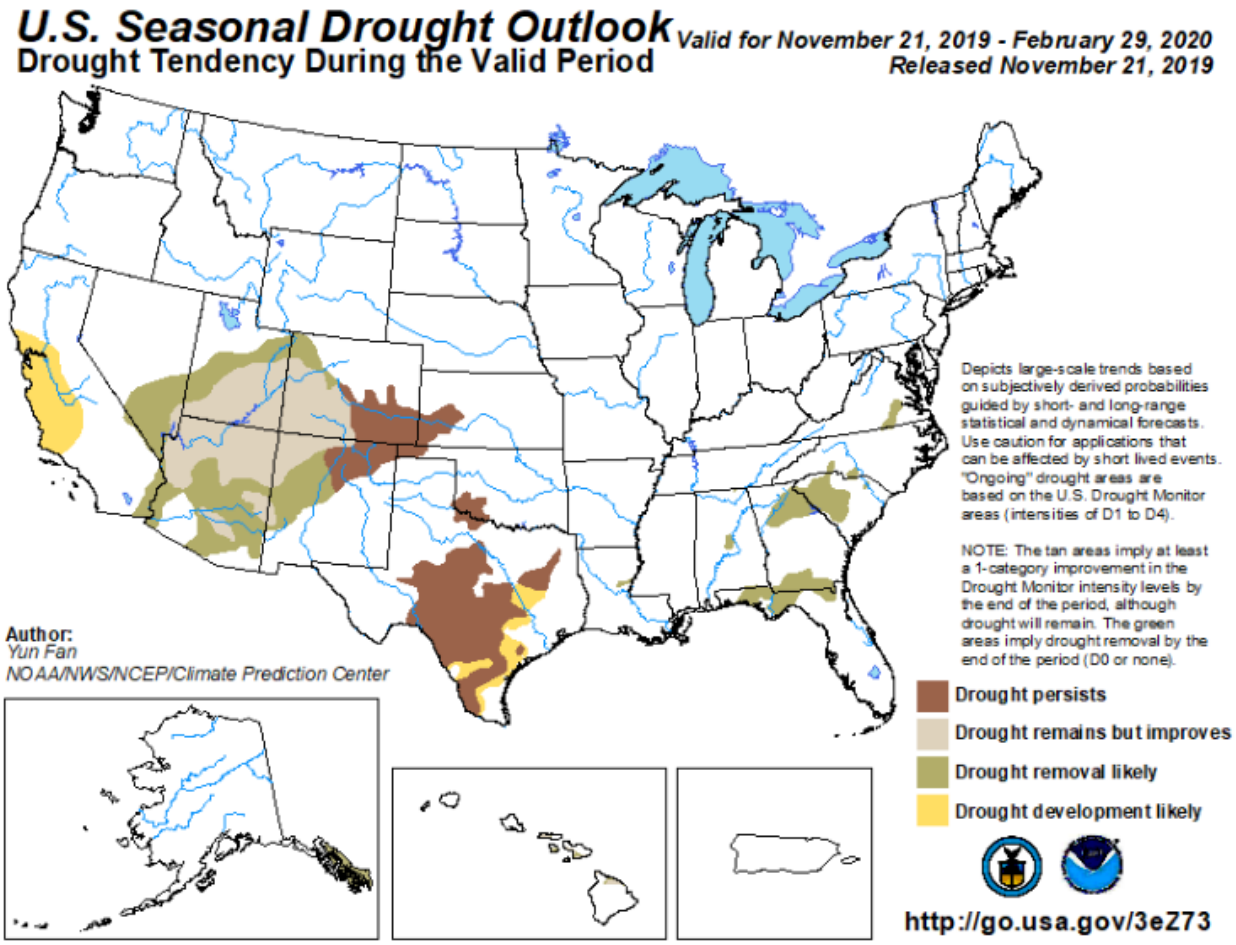


Figure 2. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. Precipitation as a percent of normal in November is shown in the top image of **Figure 3**, and September-October-November precipitation as a percent of normal is shown in the bottom image of **Figure 3**. November precipitation was quite varied across the Basin. November precipitation was greater than 200% of normal in areas of central Nebraska, northern Montana, western South Dakota, central North Dakota, and Wyoming. In contrast, areas of eastern Montana, eastern and western North Dakota, and Kansas received precipitation that was less than 25% of normal.

The three-month precipitation as a percent of normal image generally shows that precipitation was greater than normal in the northern part of the Basin, and less than normal in the southern part of the basin. Some areas of northeastern Montana and North Dakota had precipitation totals over 200% of average during the September-October-November period. This heavy precipitation over the past three months is the reason why the upper Missouri Basin continues producing well-above-average runoff.

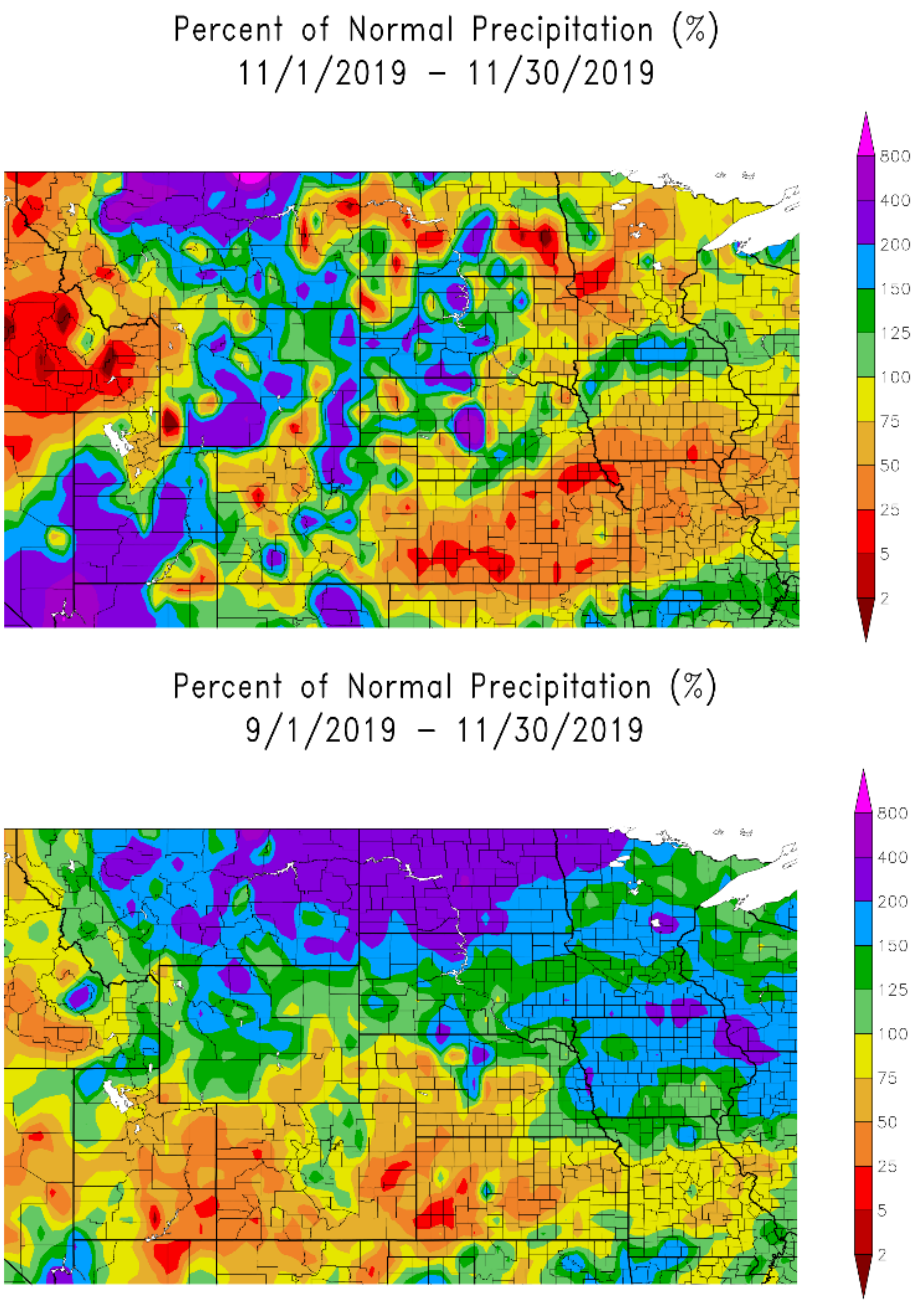


Figure 3. November 2019 and September-October-November 2019 Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature departures for November are shown in degrees Fahrenheit (deg F) in the top image of **Figure 4**. November temperatures were generally below normal, ranging from normal to about 2 degrees below normal across most of the Basin. September-October-November temperature departures, shown in the bottom image of **Figure 4,** show a below-normal temperature pattern that has impacted much of the Missouri Basin during late summer and fall**.** In most of the upper Basin, departures ranged from 1 to 4 deg F below normal.

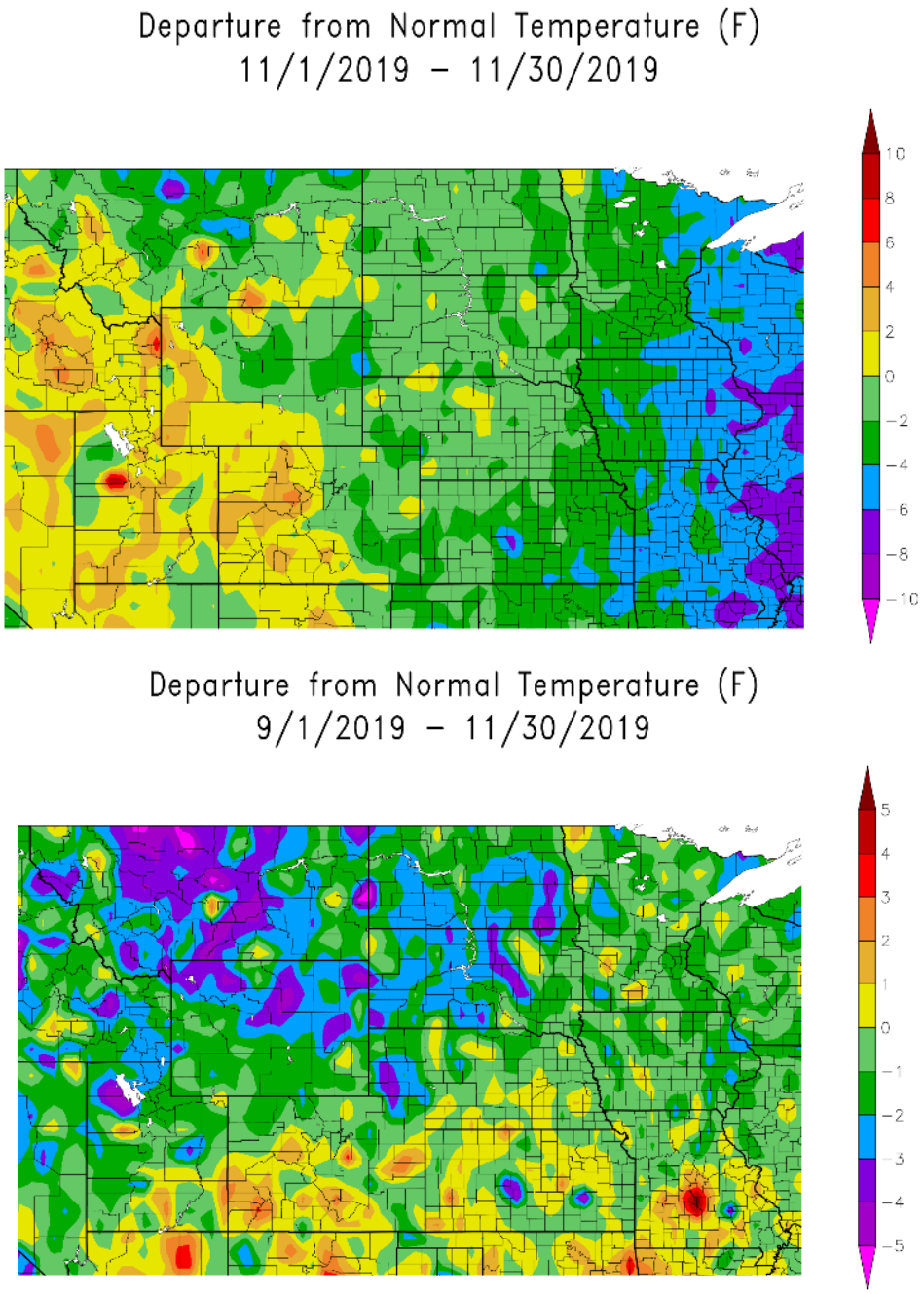


Figure 4. November 2019 and September-October-December 2019 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 5 shows the November 29, 2019 NOAA NLDAS ensemble soil moisture anomalies and soil moisture percentiles. Based on the NLDAS soil moisture anomaly map, soil moisture anomalies are well above normal everywhere in the Basin except Colorado. In terms of percentile, total soil moisture exceeds the 98th percentile, which is very wet, in much of Montana, western North Dakota, and South Dakota. Consequently, these areas will be susceptible to above-average runoff and flooding if intense rainfall occurs.

Figure 6 shows the November 30, 2019 NOAA CPC soil moisture anomalies and soil moisture percentiles. The CPC maps agree with the NLDAS maps, showing very wet soils, exceeding the 95th percentile, everywhere in the Basin except Colorado. Of particular note, soil moisture is in the 99th percentile over large portions of the upper Basin, indicating it is at its wettest or near wettest condition for this time of year.

Soil moisture at this time last year was wetter-than-normal in Montana, northern Nebraska, southeastern South Dakota, and much of Iowa. Wetter-than-normal percentiles primarily ranged from the 70th to the 90th percentile, with some isolated wet areas ranging from the 95th to 98th percentile. By comparison, 2019 soil moisture is much wetter than 2018, and over basin-wide areas compared to isolated areas in 2018.

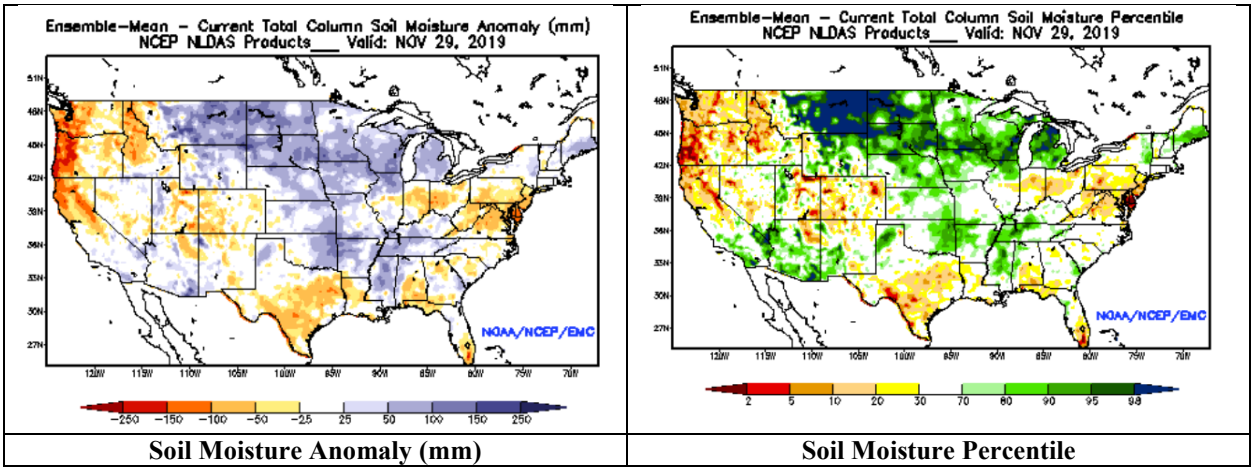


Figure 5. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

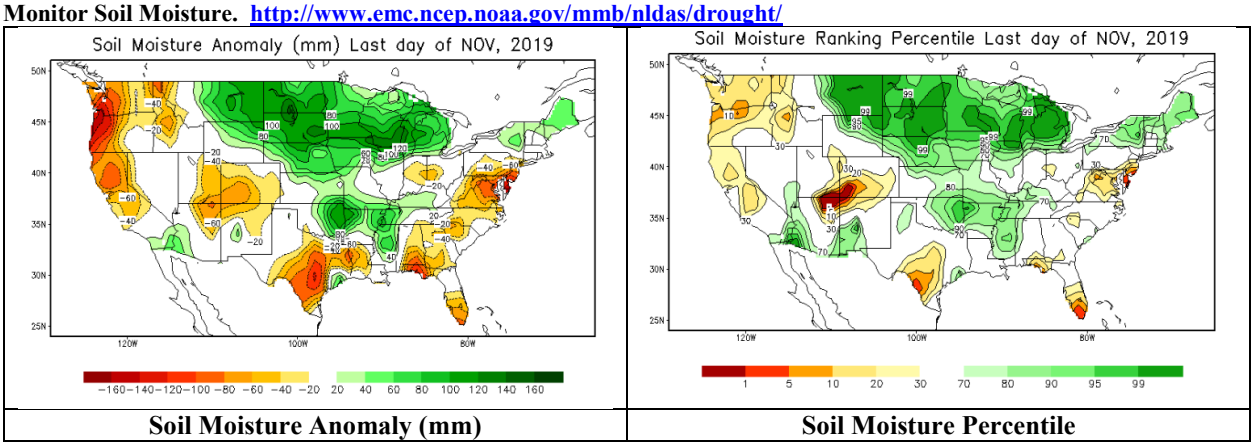


Figure 6. NOAA CPC Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA CPC. https://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml

Plains Snowpack

Plains snowpack is typically an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. However, snow accumulated on the plains during the fall in November and December can melt and contribute to runoff during those months if the temperatures are warm enough.

The National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC), modeled snow assessment from December 1, shown in **Figure 7**, indicated up to 18" of snow are present in localized areas of South Dakota, with widespread areas in North Dakota, South Dakota, Wyoming, and Nebraska of 6" or more. Great Falls, MT has received 60.4" of snow this fall, compared to the normal snowfall of 14.3". Havre, MT has received 37.2" this fall, compared to the normal depth of 8.0". Bismarck, ND has received 31.0" of snow this fall, compared to the normal snowfall of 12.0". Some of this snow has melted already, and more may melt and contribute to runoff in the upper Basin during December if temperatures remain warm.

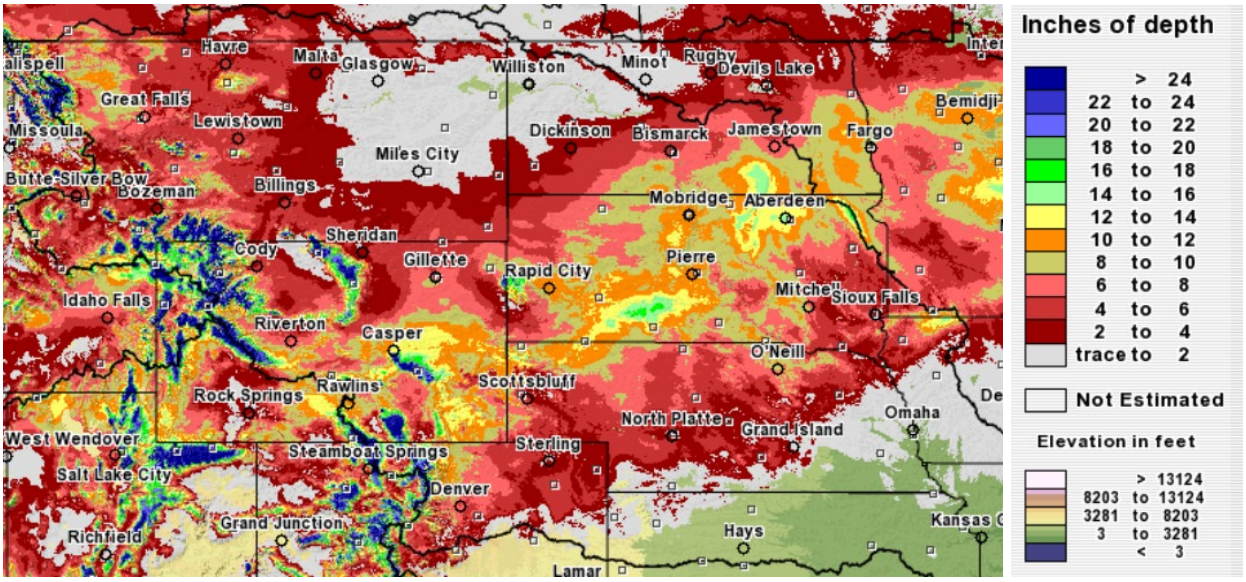


Figure 7. December 1, 2019 NOHRSC modeled plains snow depth. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The CPC's December 2, 2019 ENSO Outlook indicates that ENSO-neutral conditions are present. Equatorial sea surface temperatures are near-to-above average across much of the Pacific Ocean. ENSO-neutral conditions are favored for the fall season, continuing into spring 2020 with a 60-65% chance.

Winter Weather Outlook

The CPC issued its Winter Outlook on October 17 focusing on future climate conditions from December 2019 to February 2020. At the time of the Winter Outlook, within the Missouri Basin, the CPC indicated equal chances for temperatures in the north central U.S. with a slight tilt toward warmer-than-normal temperatures in Montana and Wyoming. With regard to precipitation, wetter conditions are likely in the upper Basin with the greatest increase in precipitation chances extending from central Montana across southern North Dakota and South Dakota. Subsequent updates to the Winter Outlook are provided in the following Temperature and Precipitation Outlooks.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

With regard to future weather, the CPC temperature outlook for December 11-17, 2019 (**Figure 8, left**) is indicating increased chances for below-normal temperatures over most of the Missouri Basin. Regarding precipitation (**Figure 8, right**), the CPC is indicating a slight increase in the chances for above-normal precipitation over most of the Basin.

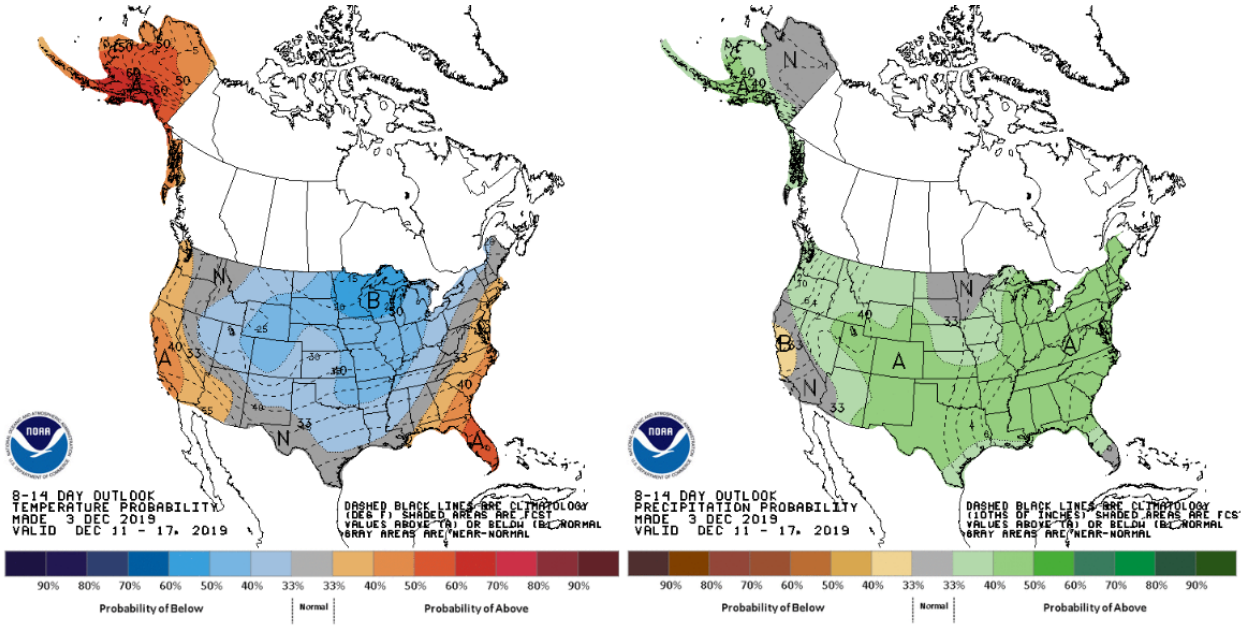


Figure 8. CPC 8-14 Day temperature and precipitation outlooks for December 11-17, 2019.

The December CPC outlooks in **Figure 9** indicate increased chances for above-normal temperatures throughout the Basin. With regard to precipitation, the CPC is indicating equal chances in Montana and western North Dakota, with increased chances for above-normal precipitation across the rest of the upper Basin.

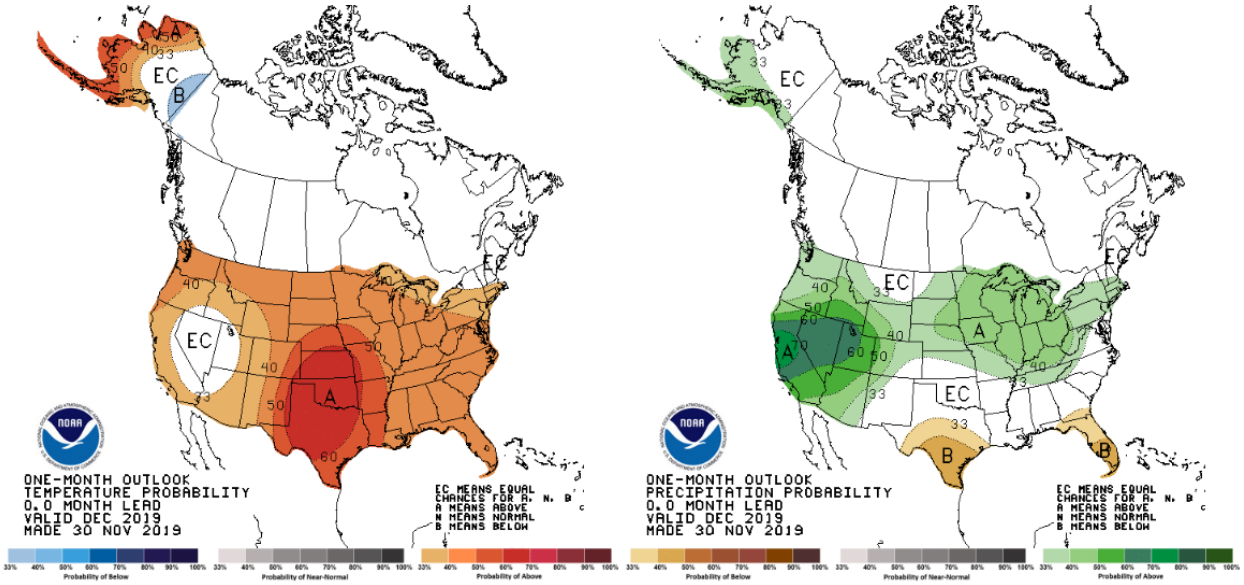


Figure 9. CPC December 2019 temperature and precipitation outlooks.

During the December 2019-January 2020-February 2020 period, the CPC outlooks in **Figure 10** are indicating equal chances for above-normal, normal, and below-normal temperatures across most of the Missouri Basin. With regard to precipitation, the CPC indicates there is an increased chance for above-normal precipitation over the Missouri Basin.

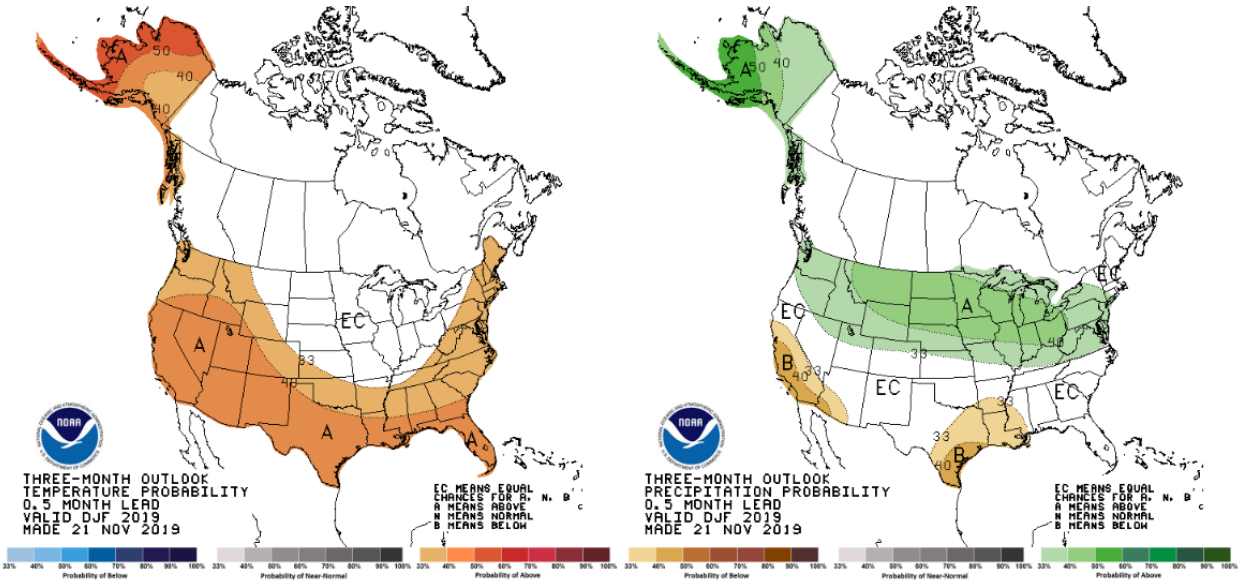


Figure 10. CPC December 2019-January 2020-February 2020 temperature and precipitation outlooks.

Summary

The updated 2019 calendar year runoff forecast is **60.4 MAF**, **238% of average**. Runoff will very likely continue to be above-average in December given the current above-average streamflow in the Basin. Future temperatures will influence the timing of river ice formation, and the volume of runoff received in December: colder-than-normal temperatures could reduce December runoff, but it is more likely that warmer temperatures could delay river ice formation, resulting in above-average December runoff. Runoff during January and February of 2020 will likely be above-average due to above-average streamflow and the outlooks indicating above-normal temperatures and above-normal precipitation. Although January and February 2020 runoff forecasts are not included in the 2019 calendar year runoff forecast, monthly reservoir studies use these runoff forecasts to extend the studies to the end of February.