Upper Missouri River Basin
December 2015 Calendar Year Runoff Forecast
December 2, 2015

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. 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 River reach above Sioux City. 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.

2015 Calendar Year Forecast Synopsis

The December calendar year runoff forecast for the Missouri Basin above Sioux City is **25.3 MAF** (100% of average). November runoff was **1.0 MAF** (100% of average) above Sioux City, and November runoff above Gavins Point was 0.8 MAF (85% of average). Observed November runoff was above average in all reservoir reaches except for the Fort Peck (73% of average) and Garrison (57% of average) reaches.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next month, the range of expected inflow ranges from the 25.5 MAF (101% of average) upper basic forecast to the 25.2 MAF (99% of average) 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 one month is being forecast for this December 1 forecast (11 months observed/one month forecast), the range of greater than expected (upper basic) and lower than expected (lower basic) runoff is attributed to all 6 reaches for one month. The result is a range or “bracket” for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

Drought conditions have persisted in the upper Missouri Basin during the fall, but have improved in the lower Basin. The drought conditions are shown in the National Drought Mitigation Center's U.S. Drought Monitor for November 24, 2015 (**Figure 1**) and October 27, 2015 (**Figure 2**). Abnormally Dry (D0) conditions (**Figure 1**) have expanded slightly in western and south central Montana, Wyoming, and western South Dakota. Moderate Drought (D1) conditions have also expanded slightly in western Montana. In the lower Basin, recent precipitation has eliminated all signs of drought in Missouri and a small portion of eastern Kansas. The U.S. Seasonal Drought Outlook through February 29, 2016 (**Figure 3)** indicates drought will persist in western Montana and the James River Basin in central North Dakota. Drought is forecast to develop in most of Montana and northwest Wyoming.

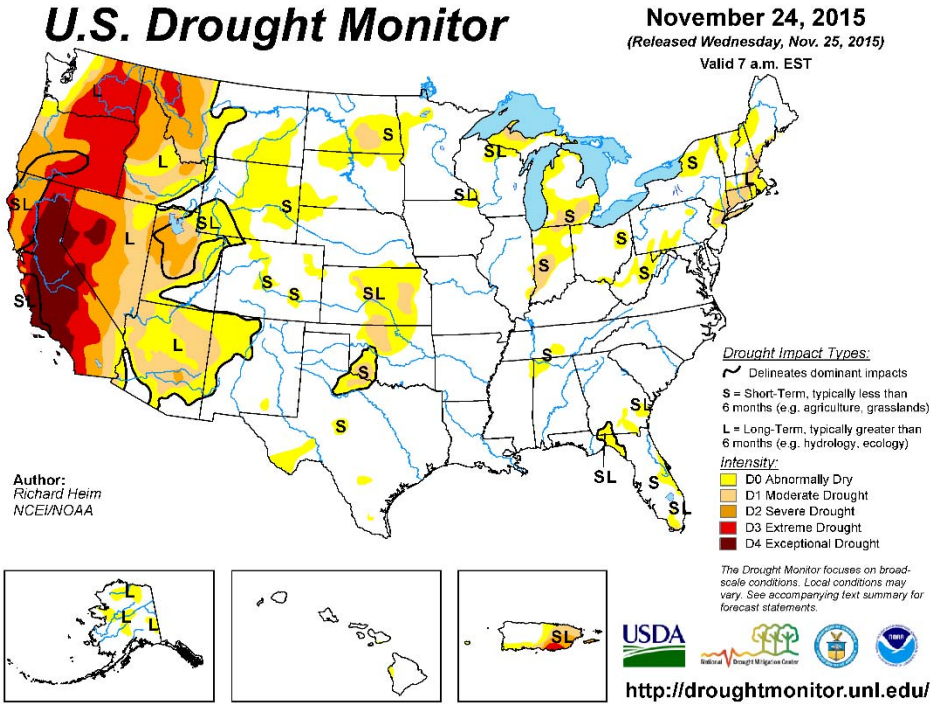

Figure 1. National Drought Mitigation Center U.S. Drought Monitor for November 24, 2015.

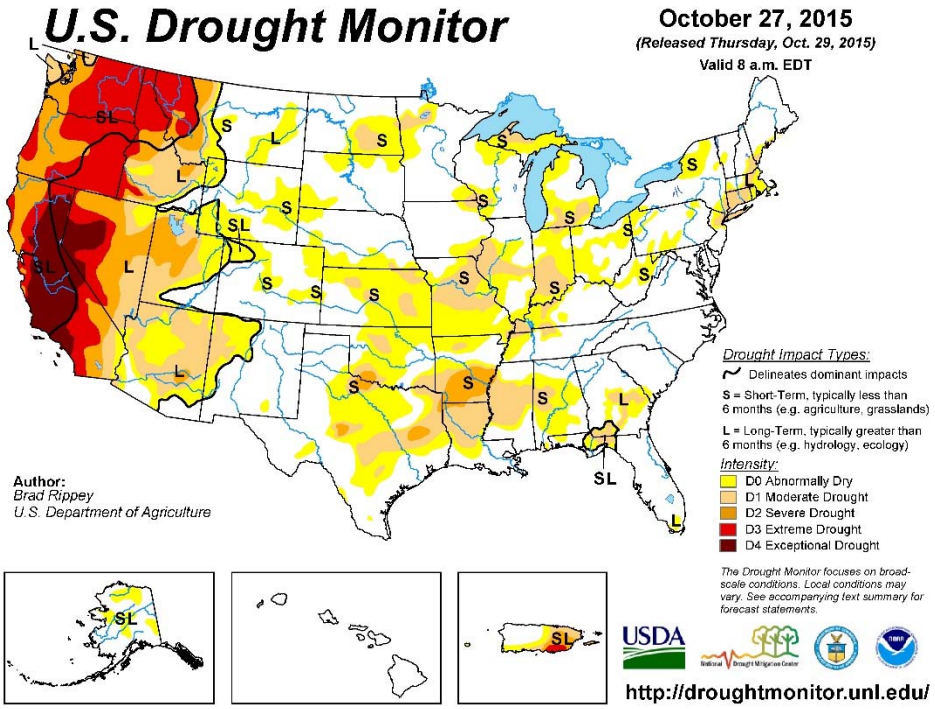

Figure 2. National Drought Mitigation Center U.S. Drought Monitor for October 27, 2015.

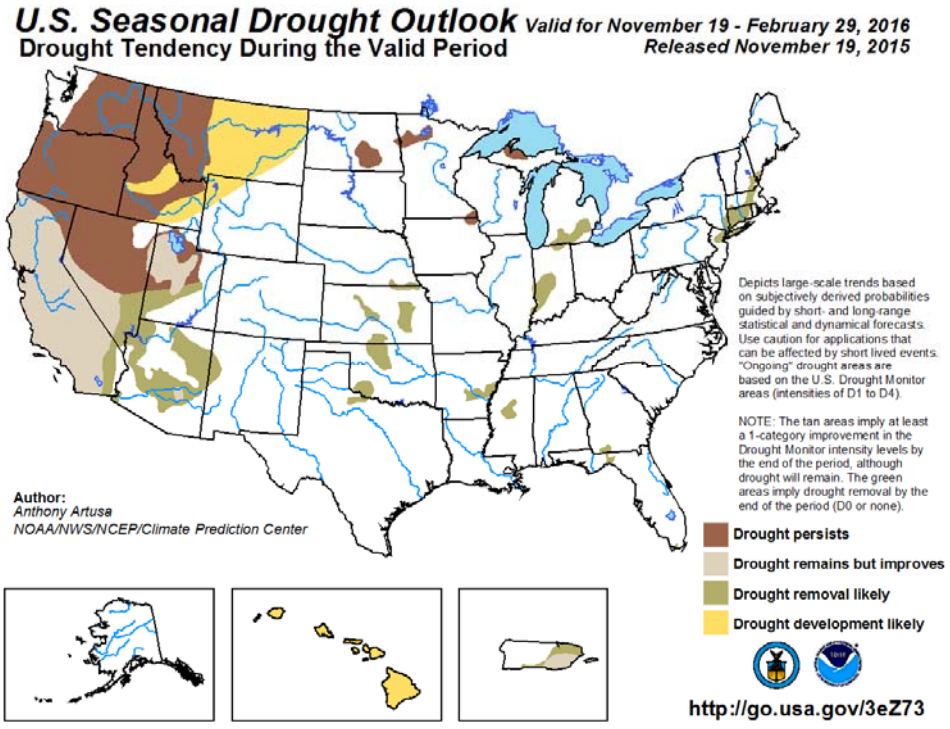

Figure 3. National Drought Mitigation Center U.S. Seasonal Drought Outlook, released November 19, 2015.

Precipitation

November precipitation accumulations are shown in **Figure 4** as both inches of precipitation and percent of normal monthly precipitation. Precipitation was above normal in western Montana and the lower Basin including Nebraska, Iowa, Kansas and Missouri. Precipitation as a percent of normal was more than 200 percent in many areas (**Figure 4, right**). Lower Basin precipitation was caused by several moderate storms resulting in total November rainfall ranging from 2 to 5 inches (**Figure 4, left**), and even greater amounts of November precipitation were observed in Missouri. In contrast upper Basin precipitation ranged from 1 to 2 inches in western Montana, but it was less than 0.5 inches over large portions of eastern Montana, northeast Wyoming and the western Dakotas (**Figure 4, left**) or less than 50% of normal (**Figure 4, right**). Precipitation was particularly low (less than 5% of normal) in an area of southwest North Dakota and northwest South Dakota.

September-October-November precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a dry pattern across much of the upper Missouri Basin including much of Wyoming, southeastern Montana, much of southern North Dakota and northern South Dakota. These areas received less than 1 inch of precipitation during the three-month period (**Figure 5, left**) or less than 50 percent of normal precipitation (**Figure 5, right**). Areas that have received above normal precipitation include northern and western Montana, northern and western North Dakota, southeastern South Dakota, Nebraska and western Iowa. Precipitation as a percent of normal in these areas has been 130 percent of normal with as much as 150 percent of normal in the wettest areas. Precipitation in the lower Basin was particularly beneficial because it resulted in high than normal Missouri River tributary flows, which benefited navigation.

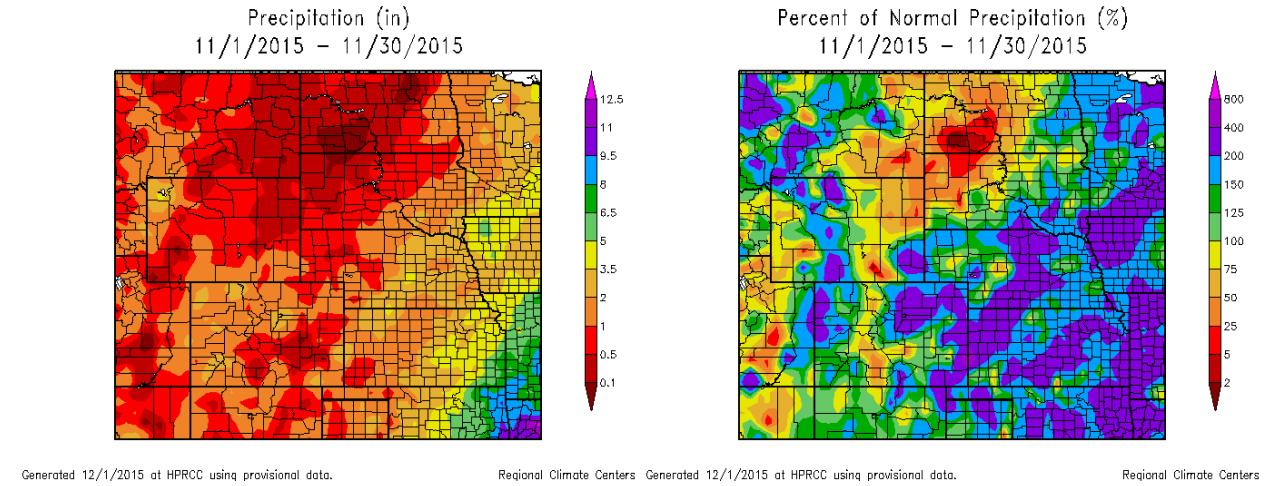

Figure 4. November 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

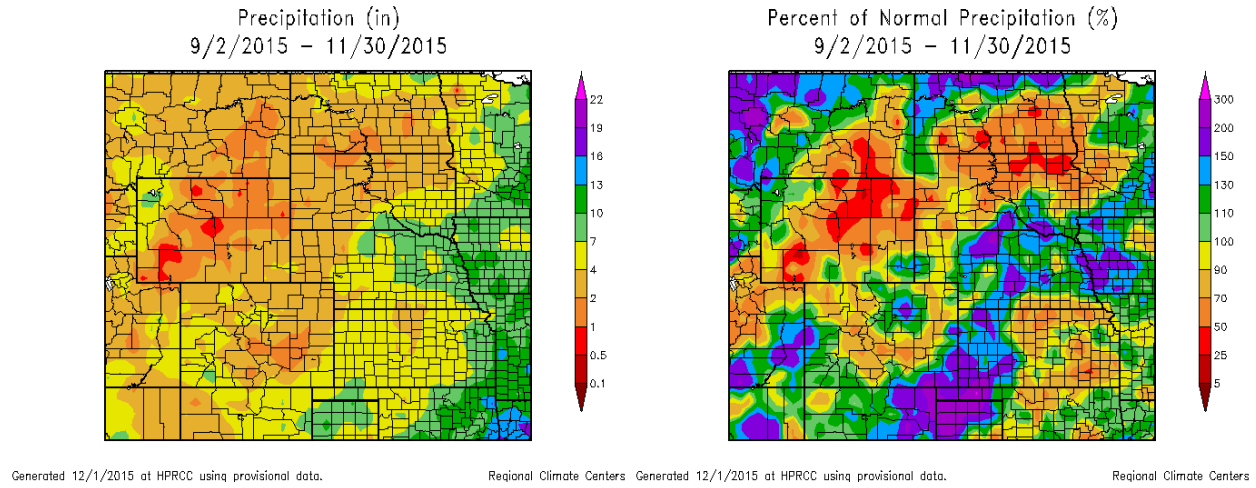

Figure 5. September-October-November 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

November temperatures shown in the left pane of **Figure 6** show a pattern of normal to about 2 deg F below normal temperatures in the western third of the upper Basin to 4 to 6 deg F above normal temperatures in the eastern third of the upper Basin. Two-month (October-November) temperature departures (**Figure 6, right**) show that most of the basin recorded 2 to 6 deg F above normal temperatures, though temperature departures ranging from 6 to 8 deg F above normal have occurred over central and eastern South Dakota and North Dakota.

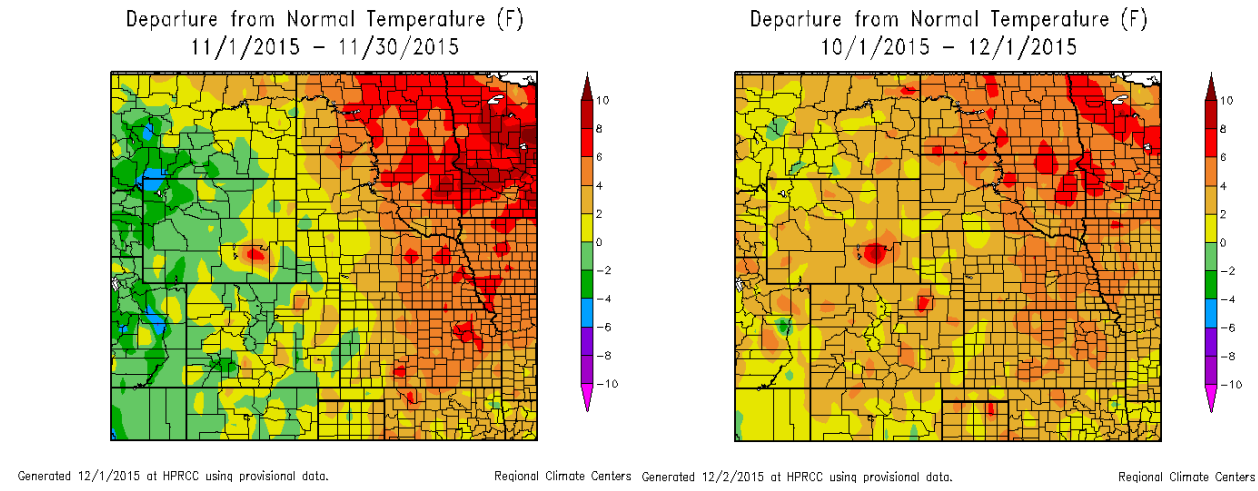

Figure 6. November 2015 and October-November 2015 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 monthly runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on November 26, 2015 for the total modeled soil column, which is about 2 meters. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above normal soil moisture conditions are persistent throughout much of the upper Basin. The wettest soils (greater than 95th percentile moisture) indicated on this map are located in north central Montana and western Iowa. Dry soils (less than 30th percentile moisture) are located in portions of western Montana, eastern North Dakota, northeast South Dakota and eastern Kansas.

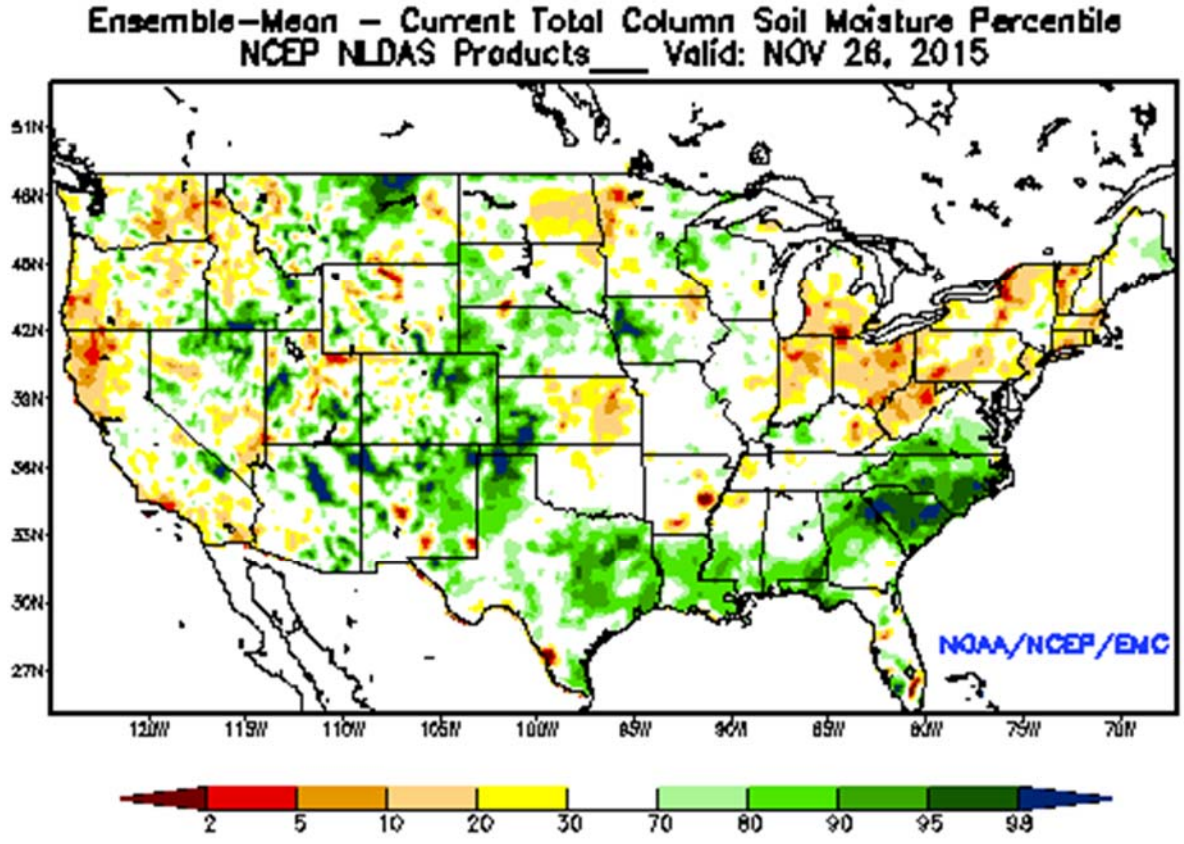

Figure 7. Total Column Soil Moisture Percentile on November 26, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 8**. These conditions are based on the ranking of the November 30, 2015 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions continue to be "Much above normal" (greater than the 90th percentile) in the Black Hills of South Dakota. Most notably, streamflow conditions in the lower Basin including Missouri River tributaries in Nebraska, Iowa, eastern Kansas and Missouri are classified as "Much above normal" (greater than the 90th percentile) to "High" as a result of above normal November precipitation. In the upper Basin, a majority of stations have no classification because the current stream gages are either ice-affected or the historical record is ice-affected. The few stations that are reporting indicate streamflow conditions, particularly in Montana and Wyoming, are "Normal" (25th-75th percentile) to "Below normal" (10th-24th percentile).

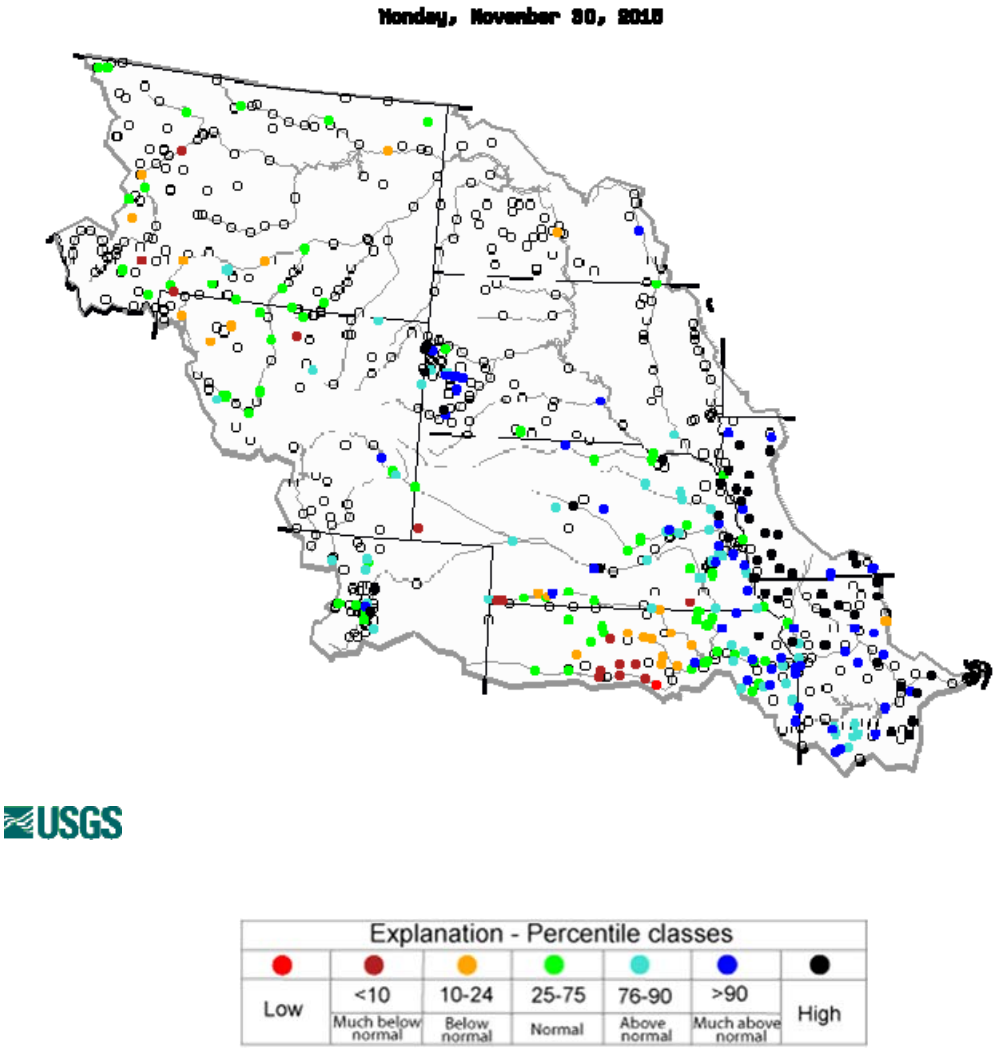

Figure 8 USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of November 30, 2015. Source: USGS. http://waterwatch.usgs.gov/index.php

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. A March-April 2016 runoff forecast will not be made until January 1, 2016.

Based on the National Operational Hydrologic Remote Sensing Center (NOHRSC) assessment (**Figure 9**) as of December 1, 2015 there were trace to 1-inch amounts of snow water equivalent (SWE) over most of the upper Missouri Basin above Sioux City, IA. Recent snowfall on November 30, 2015 over southeast South Dakota and northwest Iowa has increased accumulations to the 1 to 2 inch SWE category. Snow accumulations over southwest Iowa, northwest Missouri, southeast Nebraska and northeast Kansas are likely a combination of snow and ice accumulation. Plains snowpack in the lower Basin is expected to melt within the next week because of warmer temperatures.

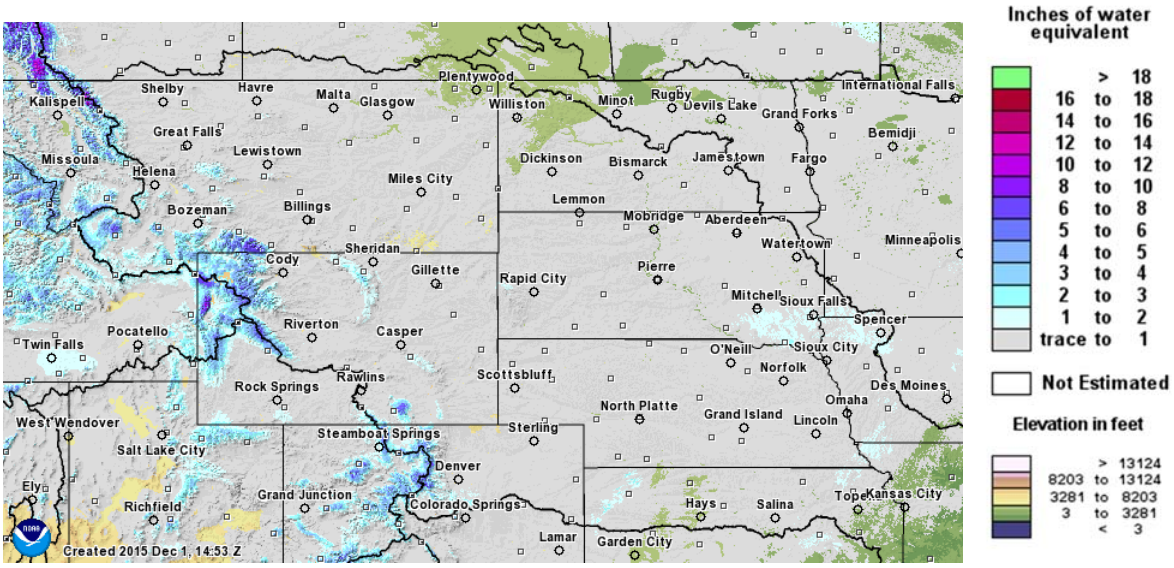

Figure 9. December 1, 2015 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Mountain Snow Pack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reaches. During the 3-month May-July runoff period, about 50% of the annual runoff enters the mainstem system as a result of mountain snowmelt and rainfall runoff. Greater than average mountain snow accumulations are usually associated with greater than average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter than normal as in the past three years. For example, we would expect to see greater than average runoff from an average mountain snowpack this year due to wetter than normal soil moisture conditions. A May-June-July 2016 runoff forecast will not be made until January 1, 2016.

Figure 10 includes time series plots of the average mountain SWE beginning on October 1, 2015 based on the NRCS SNOTEL gages 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 **November 30, 2015**, the Corps of Engineers computed an average mountain SWE in the **Fort Peck reservoir reach of 2.9 inches, which is 76% of normal** 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 **2.3 inches, which is 61% of normal** based on the 1981-2010 average SWE for the Garrison reach. Normally by December 1, 26% of the peak snow accumulation has occurred in the mountains.

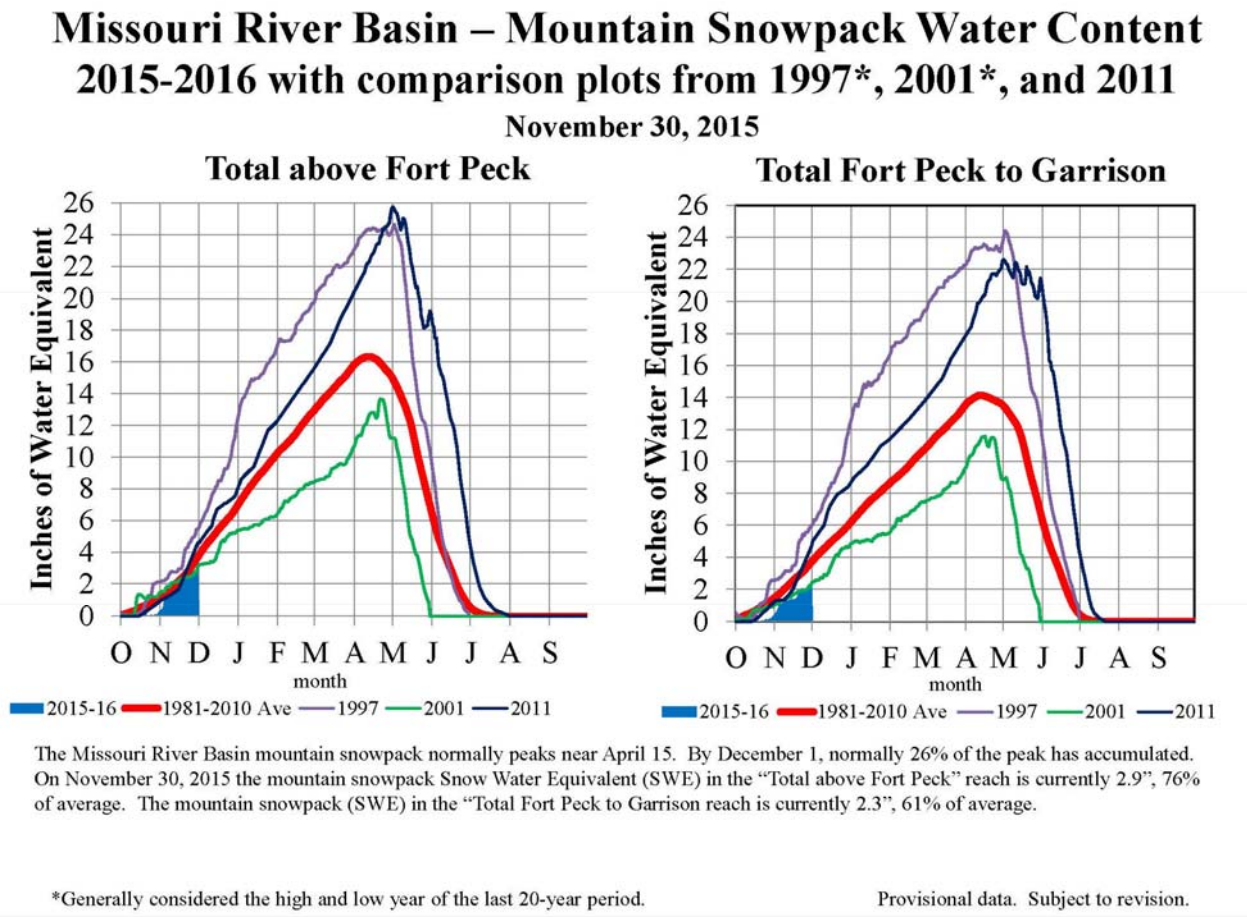

Figure 10. Mountain snowpack water content snow accumulation compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly update[1] on November 30, 2015, "***El Niño conditions are present. El Niño will likely peak during the Northern Hemisphere winter 2015-2016, with a transition to ENSO-neutral anticipate during the late spring or early summer 2016***". CPC studies are predicting a strong El Niño event at its peak. El Niño winters have a tendency to be warmer and drier than normal in the upper Missouri Basin, and the influence of El Niño has been factored into the CPC's climate outlooks.

MRBWMD 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. These webinars provide updates on near-term climate outlooks and impacts including the El Niño climate pattern and its implications on late summer, fall and early winter

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

temperature and precipitation patterns in the Missouri River Basin. The possible impacts of El Niño have been factored into the CPC climate outlooks described below.

Temperature and Precipitation Outlooks

For December (**Figure 11**), the CPC temperature outlook indicates increased chances for above normal temperatures in nearly all of the Missouri Basin. The greatest probabilities for **above normal temperatures** are forecast for the portion of the Missouri Basin east of the Missouri River including much of North Dakota, eastern South Dakota and Iowa. With regard to precipitation, the CPC indicates that there are increased chances for **below normal precipitation** in the upper Basin including Montana, North Dakota, northern and central Wyoming and northwest South Dakota. There are increased chances for **above normal precipitation** in Colorado, southwest Nebraska and western Kansas. There are equal chances in the remainder of the Basin including eastern Nebraska, Iowa and Missouri.

During December-January-February (**Figure 12**), the CPC outlook portrays a similar forecast: increased chances for **above normal temperatures** in the upper Basin, but equal chances in Colorado, Kansas and southern Missouri. For precipitation, the CPC outlook indicates increased chances for **below normal precipitation** in Montana, Wyoming, North Dakota and northern South Dakota. In southern portions of the Basin, there is a higher probability for **above normal precipitation** over portions of Colorado, Kansas and much of Nebraska.

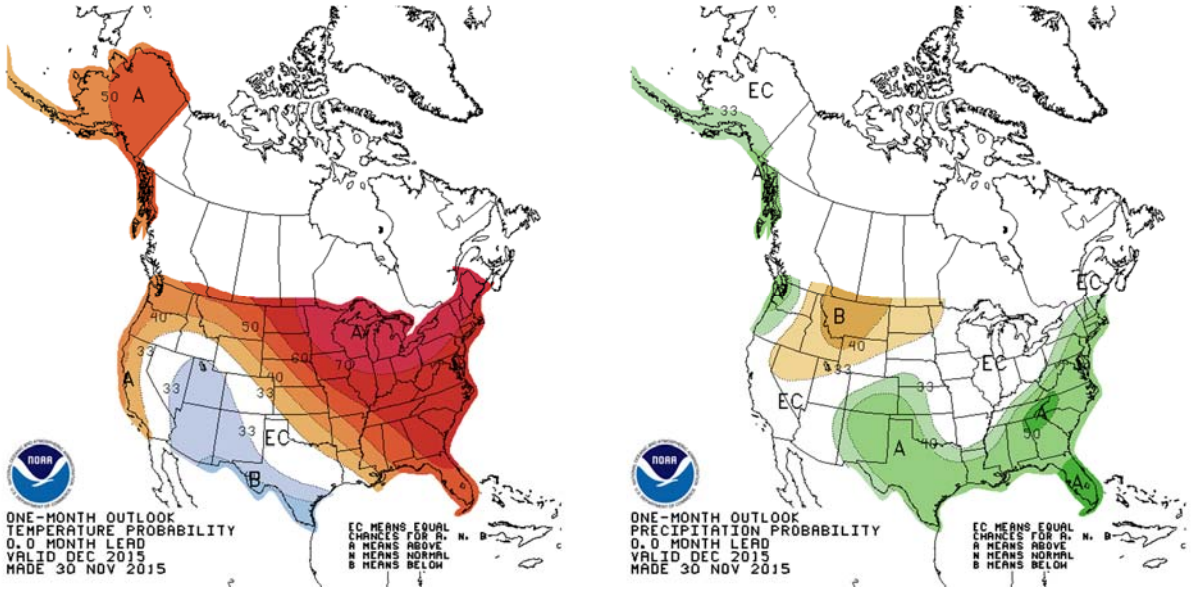

Figure 11. CPC December 2015 temperature and precipitation outlooks.

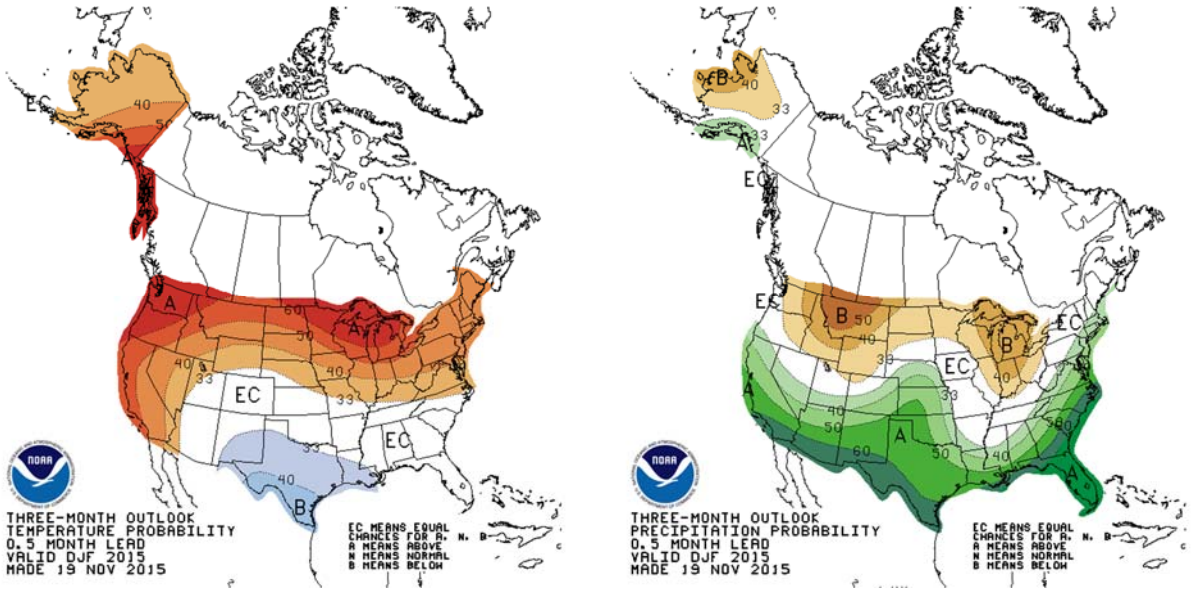

Figure 12. CPC December 2015-January-February 2016 temperature and precipitation outlooks.

December 2015 Calendar Year Runoff Forecast

The December calendar year runoff forecast for the Missouri Basin above Sioux City is **25.3 MAF** (100% of average). For the Basin above Gavins Point Dam, the 2015 calendar year runoff forecast is 22.9 MAF (99% of average).

Observed November runoff was 1.0 MAF (100% of average) above Sioux City. Observed November runoff was 0.8 MAF (85% of average) above Gavins Point Dam. November runoff was above average in all reservoir reaches except for the Fort Peck reach (73% of average) and the Garrison reach (57% of average).

Runoff in December is expected to continue along a similar trend as the past few months. December runoff above Sioux City is forecast to be 690 kAF (92% of average) while runoff above Gavins Point Dam is forecast to be 570 kAF (82% of average).