Upper Missouri River Basin
October 2016 Calendar Year Runoff Forecast
October 12, 2016

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.

September 2016 Runoff

September 2016 Missouri River Basin above Sioux City, IA (upper Basin) runoff was 1.0 MAF (91% of average). September runoff was 62% of average in the Fort Peck reach, 62% of average in the Garrison reach, 87% of average in the Oahe reach, 157% of average in the Fort Randall reach, 114% of average in the Gavins Point reach, and 259% of average in the Sioux City reach. Dry antecedent soil moisture conditions at the beginning of September led to below-average runoff in the Fort Peck, Garrison and Oahe reaches. Above-average runoff in the Sioux City reach was due to higher-than-average precipitation during September.

2016 Calendar Year Forecast Synopsis

The October 1 forecast for 2016 upper Basin runoff is **22.7 MAF (90% of average)**. Runoff for the basin above Gavins Point Dam is forecast to be **19.0 MAF (82% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 3 months, the range of expected inflow ranges from the 23.3 MAF upper basic forecast to the 22.1 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 3 months are being forecasted for this October 1 forecast (9 months

observed/3 months forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all 6 reaches for 3 months. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for September 27, 2016 (**Figure 1**), when compared to the drought monitor for August 30, 2016 (**Figure 2**), shows a mix of increased and decreased severity and areal extent of drought conditions in the upper Basin. There has been some worsening of drought conditions in southwestern Montana and northwestern Wyoming, but improvement of drought conditions in northeastern Wyoming and western South Dakota. Moderate (D1) to Severe (D2) drought conditions persist in western Montana, northwestern and northeastern Wyoming and western South Dakota. There is a small area of Extreme (D3) drought in northwestern South Dakota and northeastern Wyoming. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought conditions are expected to improve in all areas except for northwestern South Dakota, where drought conditions are expected to persist.

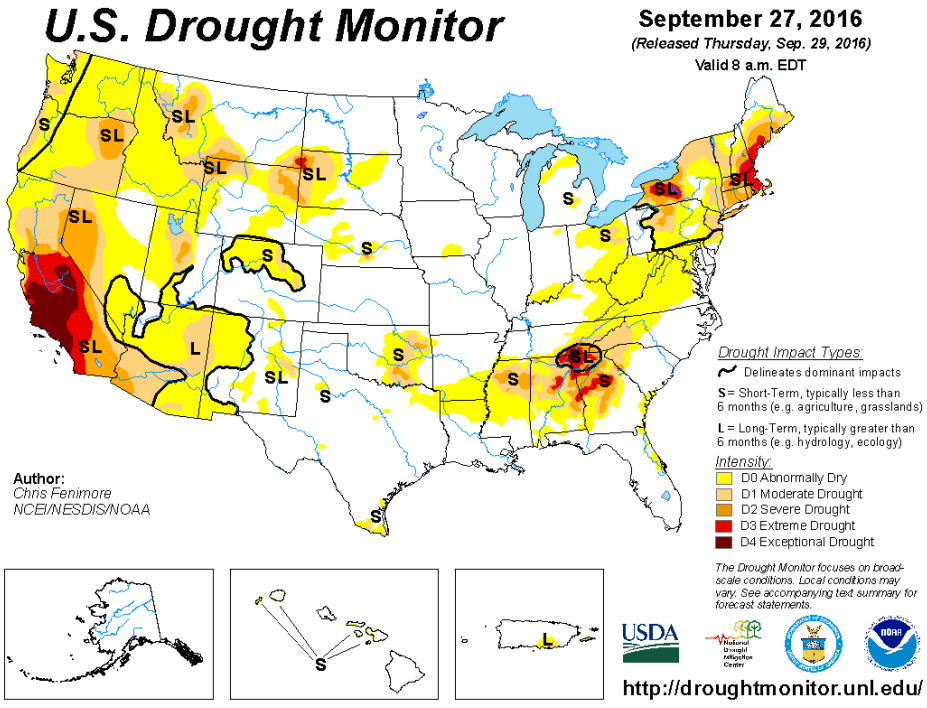

Figure 1. National Drought Mitigation Center U.S. Drought Monitor for September 27, 2016

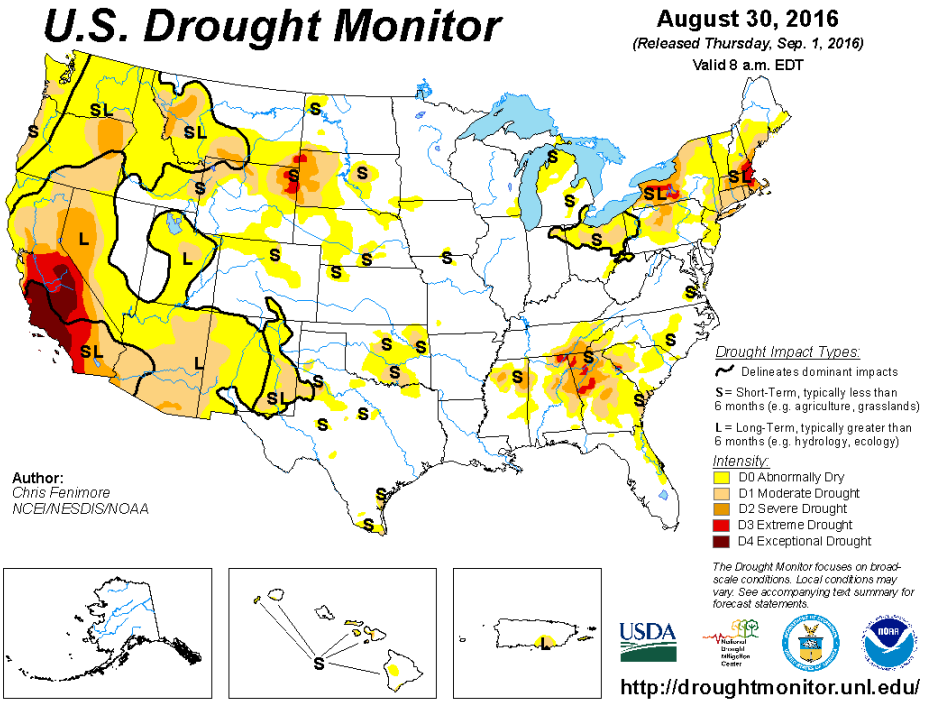

Figure 2. National Drought Mitigation Center U.S. Drought Monitor for August 30, 2016

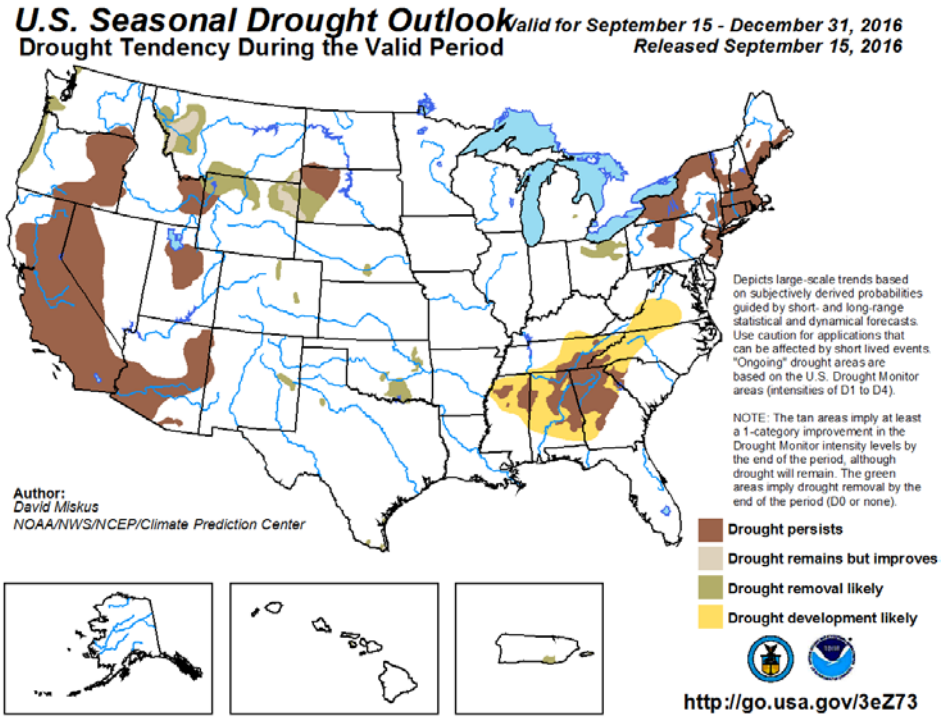

Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

September precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). September precipitation occurred along two major storm tracks or paths in the Missouri Basin. The first track extended across Wyoming, Montana and North Dakota. Storms on this track produced September precipitation totals in these states ranging from 150 to nearly 400 percent of average. The second track extending across Kansas, eastern Nebraska, southeastern South Dakota and Iowa also produced areas of heavy precipitation. Precipitation was well-below average between these tracks over Colorado, western Nebraska and South Dakota.

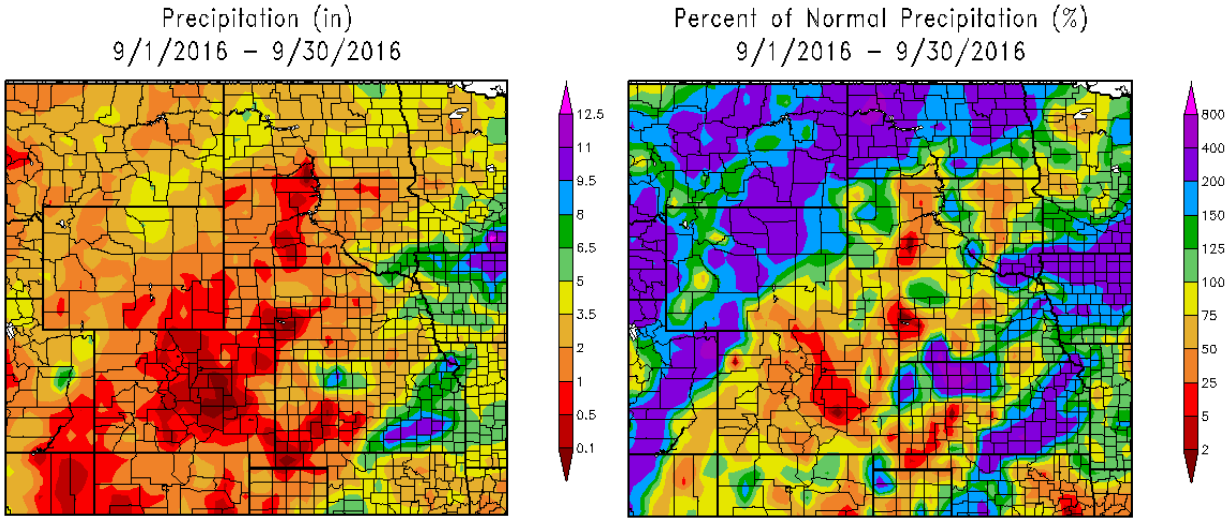

Figure 4. September 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

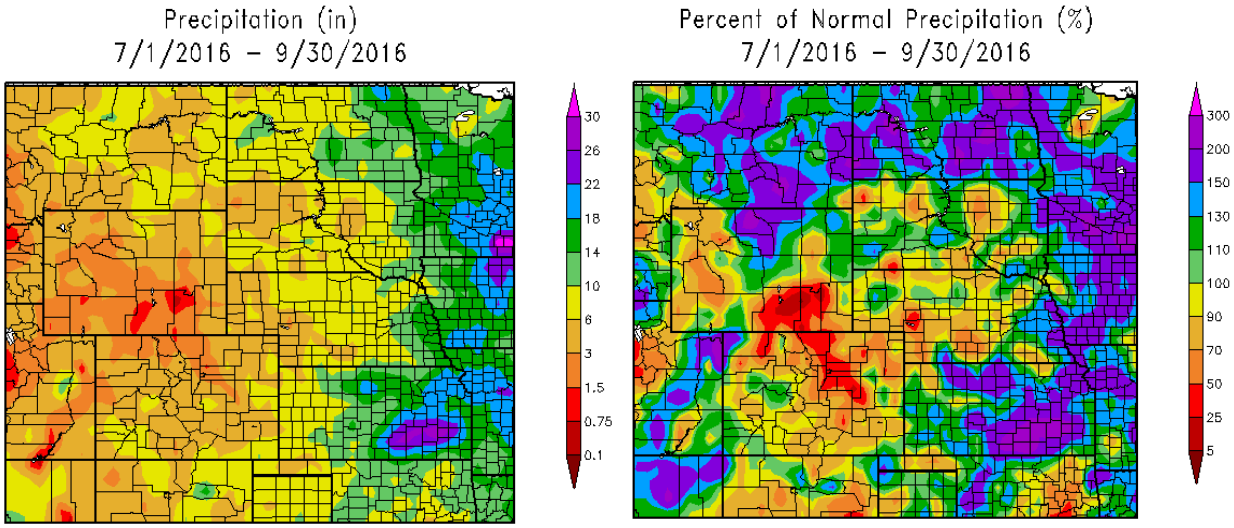

Figure 5. July-August-September 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

July-August-September 2016 precipitation accumulations and percent of normal precipitation are shown in **Figure 5**. The precipitation pattern since July 1 has been very wet (130-200% of normal) over much of Montana, northern Wyoming, North Dakota, eastern Nebraska, Iowa, Kansas and Missouri. Areas that have received below normal precipitation include western and southern Wyoming, portions of South Dakota, Colorado and western Nebraska.

Table 1 contains notable September 2016 precipitation amounts and precipitation departures in many locations in the Missouri Basin. High September precipitation totals as a percent of normal occurred in many upper Basin locations in Montana and Wyoming, and lower Basin locations in Nebraska, Kansas and Missouri. Below average precipitation totals occurred at locations in central South Dakota. A few notable above average precipitation totals occurred at Miles City, MT (259%); Wolf Point, MT (231%); Sheridan, WY (259%); Williston, ND (334%); Sioux Falls, SD (175%); Omaha, NE (165%); St. Joseph, MO (253%); and, Columbia, MO (189%).

Table 1. September 2016 precipitation and precipitation departures.

City, State	Precipitation inches	Precipitation Departure inches	Percent of Normal
Dillon, MT	1.48	0.61	170
Great Falls, MT	2.22	0.80	156
Billings, MT	1.58	0.28	122
Livingston, MT	1.64	0.43	136
Miles City, MT	2.80	1.72	259
Glasgow, MT	1.67	0.73	178
Wolf Point, MT	2.31	1.31	231
Lander, WY	1.68	0.63	160
Lake Yellowstone, WY	2.65	1.35	204
Sheridan, WY	3.71	2.28	259
Cheyenne, WY	0.80	-0.68	54
Denver, CO	0.28	-0.68	29
Jamestown, ND	3.91	1.91	196
Williston, ND	3.54	2.48	334
Rapid City Arpt, SD	1.22	-0.37	77
Watertown, SD	2.06	-0.58	78
Pierre, SD	1.23	-0.64	66
Mitchell, SD	2.15	-0.17	93
Sioux Falls, SD	7.55	3.24	175
Sioux City, IA	2.78	-0.18	94
North Platte, NE	0.94	-0.47	67
Grand Island, NE	2.53	0.30	113
Omaha, NE	4.42	1.74	165
Manhattan, KS	3.62	0.45	114
Topeka, KS	7.78	4.12	213
Lawrence, KS	6.12	1.96	147
St. Joseph, MO	8.66	5.24	253
Kansas City Intl Arpt, MO	4.94	0.32	107
Columbia, MO	7.33	3.46	189
St. Louis, MO	4.95	1.82	158

Temperature

September temperature departures from normal are shown in the left image of **Figure 6** in degrees Fahrenheit (deg F). July-August-September 2016 temperature departures from normal are shown in the right image of **Figure 6**. Across much of the upper Basin and lower Basin, temperature ranged from 1 to 4 deg F above normal. In Montana temperature departures varied from slightly cooler than normal in western Montana to above normal in eastern Montana. Temperature departures during the July-August-September period in the right image of **Figure 6** have been normal to slightly cooler than normal in the upper Basin. In the lower basin temperatures have ranged from normal to about 2 deg F above normal.

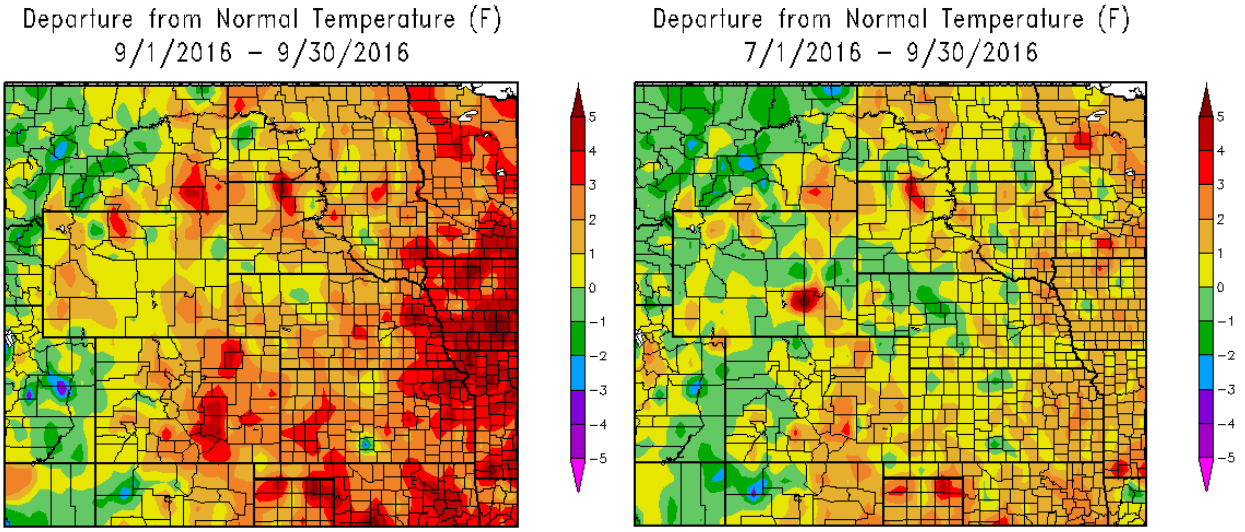

Figure 6. September 2016 and July-August-September 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 NOAA NLDAS ensemble top one-meter soil moisture anomaly on September 27, 2016. The NLDAS soil moisture depiction is an average value for the one-meter soil moisture column. **Figure 7** indicates that soil moisture is predominantly wetter than normal (above normal anomalies) over large portions of Montana, Wyoming, North Dakota, eastern Nebraska, Iowa, Kansas and portions of Missouri. Drier than normal soil moisture conditions (below normal anomalies) are present in western Montana, northwestern and southeastern Wyoming, South Dakota, Colorado and much of Nebraska. As the calendar year approaches

winter, the wet and dry soil moisture conditions will provide some insight into late winter and early spring runoff potential.

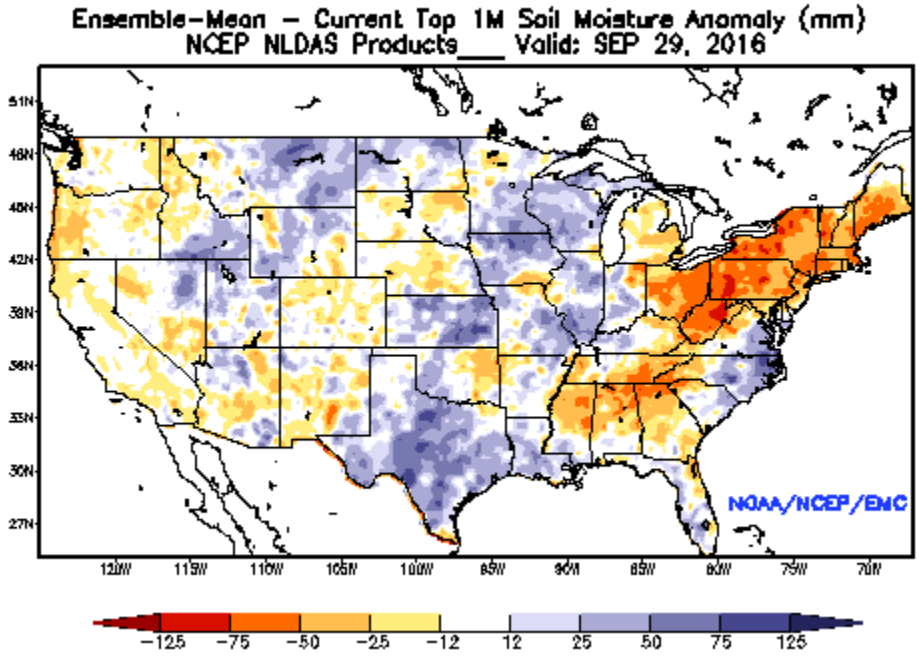

Figure 7. Top 1-Meter Soil Moisture Anomaly on September 29, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 8**. These conditions are based on the ranking of the October 3, 2016 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions were generally "Normal" (25th-75th percentile) and "Below Normal (10th to 24th percentile) in Montana and Wyoming with the exception of a few streams that were "Above Normal" (75th – 90th percentile). Streamflow between Garrison Dam and Gavins Point Dam was generally "Normal" (25th – 75th percentile), while most of the Missouri River below Gavins Point Dam was "Above Normal" (75th – 90th percentile) to "Much Above Normal" (above 90th percentile) due to wetter than normal soil moisture and above average precipitation in portions of the lower Basin.

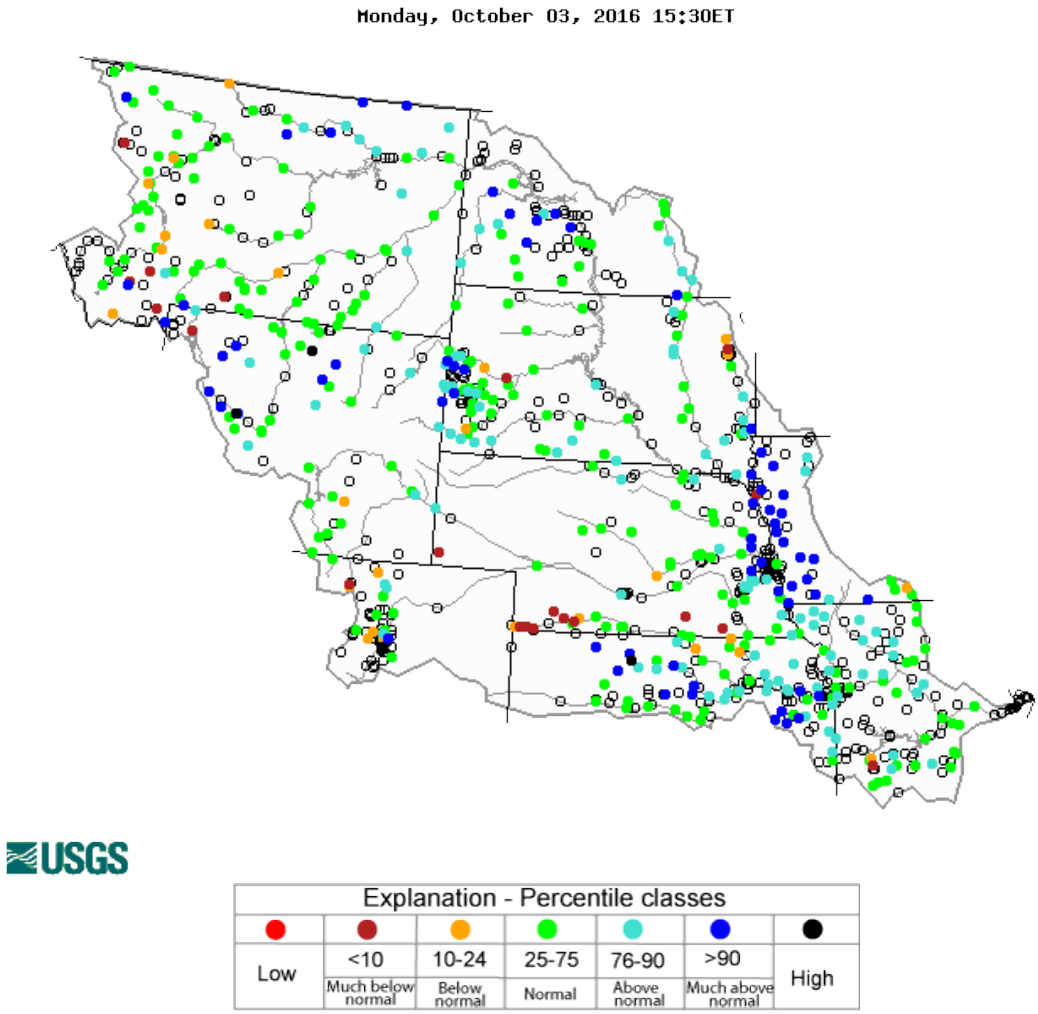

Figure 8. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of October 3, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Climate Outlook

ENSO (El Niño Southern Oscillation)

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 (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 River Basin.

The CPC ENSO climate update, posted October 3, indicated ENSO neutral conditions were present in the equatorial Pacific Ocean. ENSO-neutral conditions are slightly favored (between 55-60%) during the fall and winter 2016-2017, and a La Niña winter is no longer anticipated. ENSO-neutral conditions add some uncertainty to the winter weather outlooks.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for October 2016 (**Figure 9)** indicates there is a slight increase in the chances for above-normal temperatures throughout the entire Basin. With regard to precipitation, there are increased chances for above-normal precipitation in the upper Basin and portions of the lower Basin including western Iowa and Nebraska. So far in October, precipitation in Montana, western North Dakota, and western Wyoming has been well-above normal.

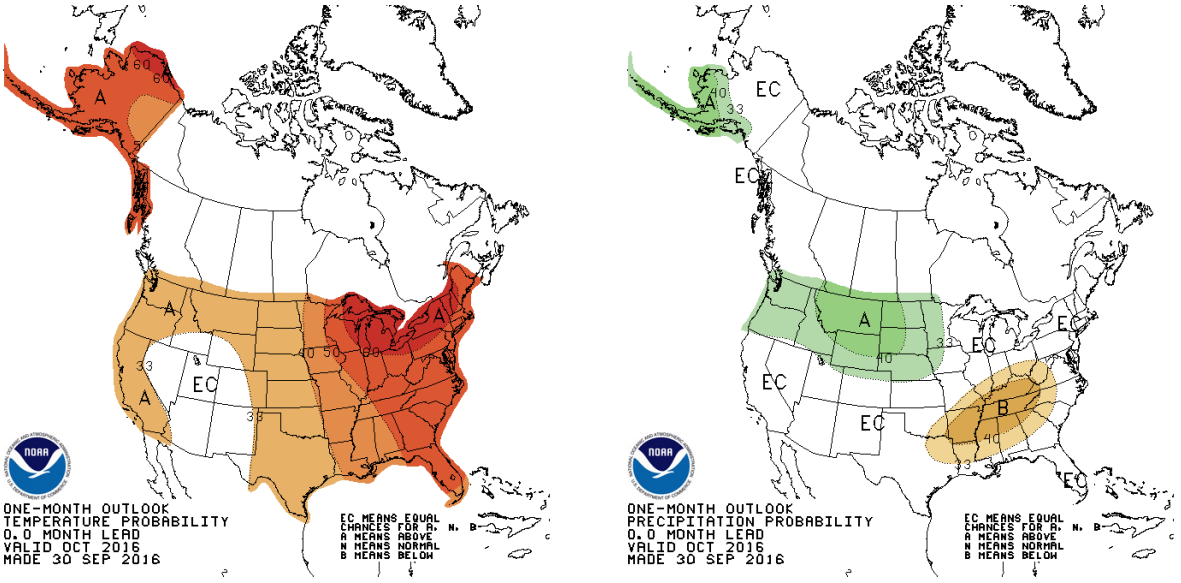

Figure 9. CPC October 2016 temperature and precipitation outlooks.

The October-November-December 2016 temperature outlook (**Figure 10**) indicates there are increased chances for above-normal temperatures throughout the entire Missouri Basin, particularly in the mountains. With regard to precipitation, there are increased chances for above-normal precipitation in Montana. There are equal chances for above-normal, normal or below-normal precipitation over the remainder of the Missouri Basin.

The January-February-March 2017 CPC temperature outlook (**Figure 11**) indicates there are increased chances for below-normal temperatures across the northern plains extending through northeastern Montana, North Dakota, and northern South Dakota. There are equal chances for above-normal, normal or below-normal temperatures across the remainder of the Missouri Basin. With regard to precipitation, there are increased chances for above-normal precipitation across Montana and the northern half of Wyoming. There are equal chances for precipitation in the remainder of the Missouri Basin from January through March 2017.

During the April-May-June 2017 period (**Figure 12**) CPC outlooks indicate equal chances for above-normal, normal and below-normal temperatures in most of the upper Basin, and increased chances for above-normal temperatures in the lower Basin. There are equal chances for above-

normal, normal and below-normal precipitation across the Missouri Basin, with the exception of a slight increase in the chances for above normal precipitation in North Dakota.

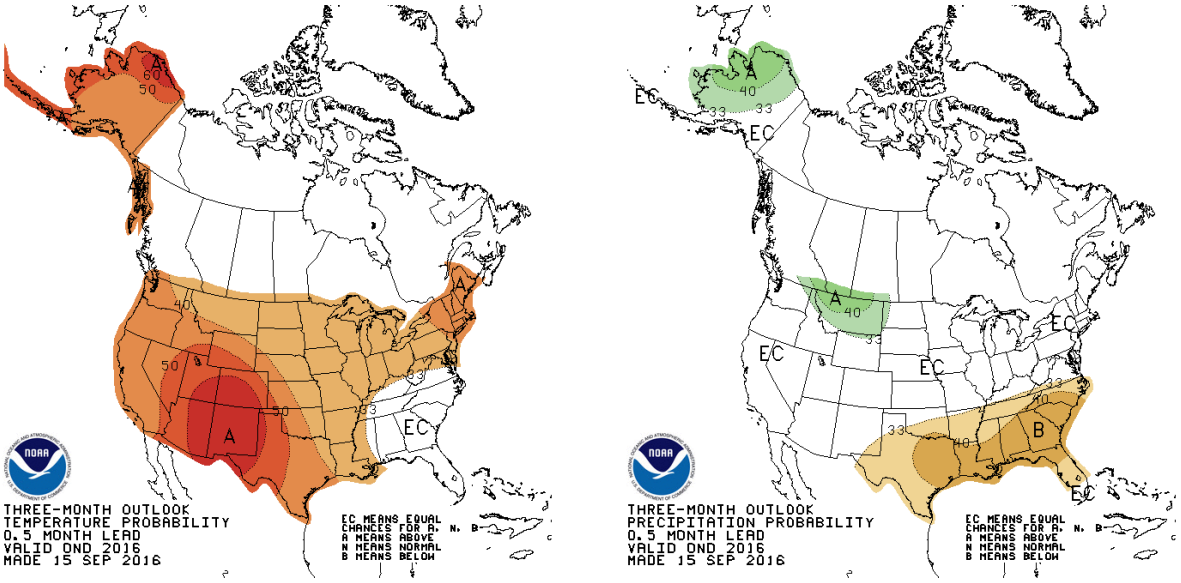

Figure 10. CPC October-November-December 2016 temperature and precipitation outlooks.

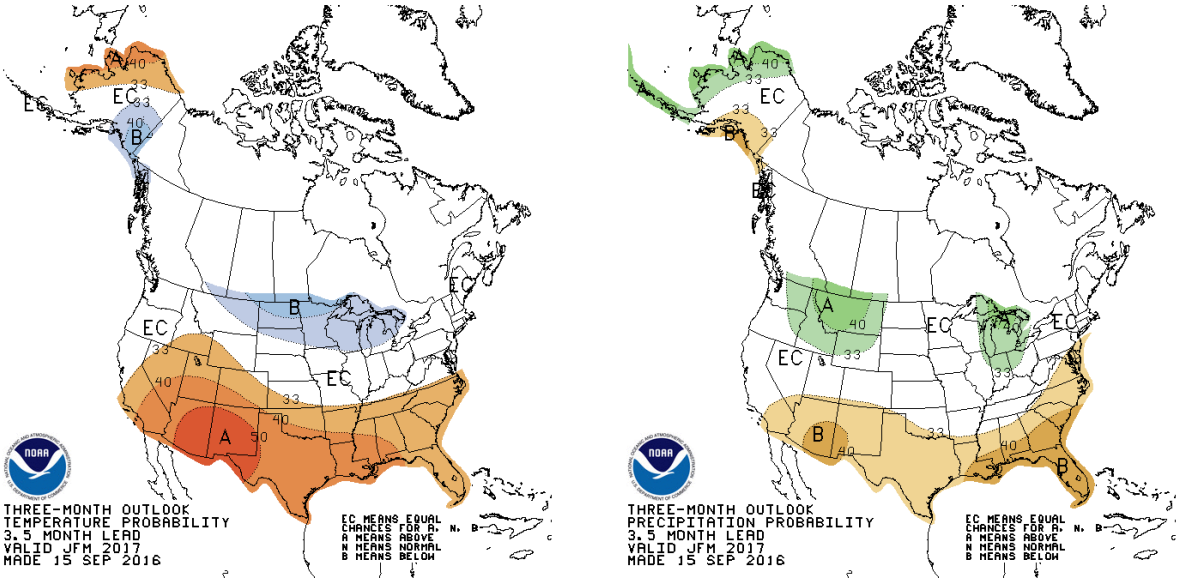

Figure 11. CPC January-February-March 2017 temperature and precipitation outlooks.

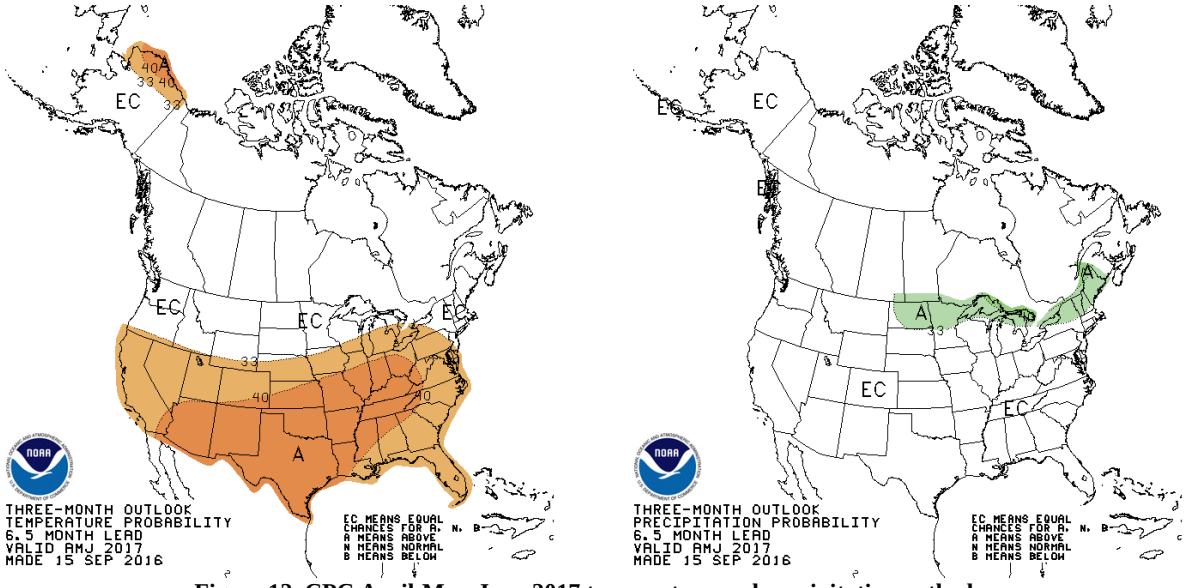

Figure 12. CPC April-May-June 2017 temperature and precipitation outlooks.

October 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **22.7 MAF, 90% of average**. Runoff for the basin above Gavins Point Dam, excluding the contributing area between Gavins Point Dam and Sioux City, IA, is forecast to be **19.0 MAF (82% of average)**. September runoff was 1.0 MAF (91% of average). Runoff was 62% of average in both the Fort Peck and Garrison reaches, despite the well-above average rainfall during September. Precipitation outlooks for the mountain and plains regions of the upper Basin indicate increased probabilities for above normal precipitation through the end of the calendar year. Winter precipitation, which normally comes in the form of mountain or plains snow, will have little impact on runoff during the 2016 calendar year. We will continue to monitor Missouri Basin conditions and make forecast adjustments as conditions change.