Upper Missouri River Basin
February 2016 Calendar Year Runoff Forecast
February 5, 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.

January 2016 Calendar Year Runoff

January 2016 Missouri River runoff was 0.9 MAF (114% of average) above Sioux City, IA (Upper Basin). January 2016 runoff above Gavins Point Dam was 0.7 MAF (100% of average). Runoff early in the month was limited due to cold temperatures in the Upper Basin causing the initial Missouri River freeze-up. From mid-January to the end of the month, warmer-than-normal temperatures caused some plains snowmelt and river ice melt causing increased runoff during the last week of January.

2016 Calendar Year Forecast Synopsis

The February 1 forecast for the 2016 Missouri River runoff above Sioux City, IA is **23.3 MAF (92% of average)**. Runoff above Gavins Point Dam is forecast to be **20.9 MAF (90% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 11 months, the range of expected inflow is quite large and ranges from the 32.0 MAF upper basic forecast to the 15.5 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 11 months are being forecasted for this February 1 forecast (1 months observed/11 months forecast), the range of wetter than normal (upper basic) and lower than normal (lower basic) is attributed to all 6 reaches for 11 months. The result is a large range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for January 26, 2016 (**Figure 1**), when compared to the drought monitor for December 29, 2015 (**Figure 2**), shows increased development of Abnormally Dry (D0) and Moderate Drought (D1) conditions in north central Wyoming, southeast Montana, and southeast North Dakota. In contrast, there has been a slight contraction of all drought conditions in western Montana. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought will persist in western and southeastern Montana, north central Wyoming and south central North Dakota. New drought conditions will likely develop in central Montana through the end of April 2016.

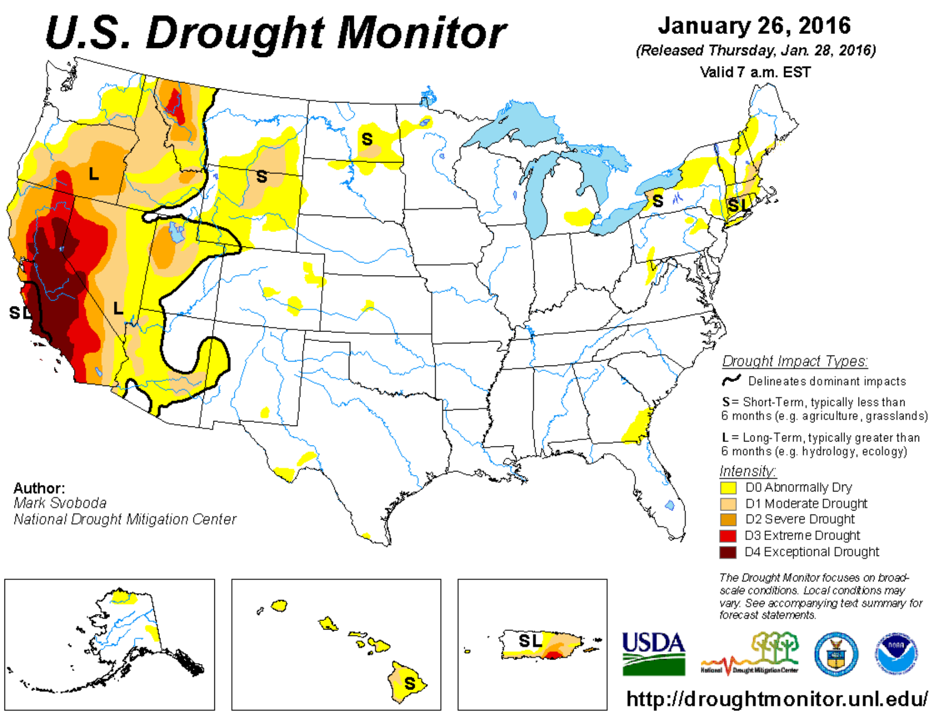


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for January 26, 2016.

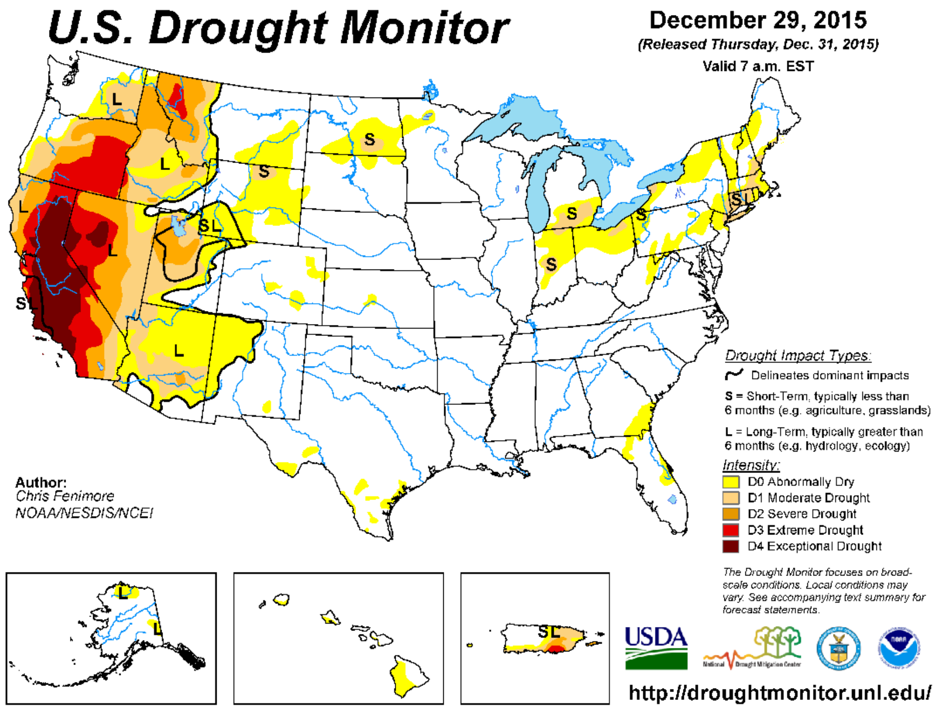


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for December 29, 2015.

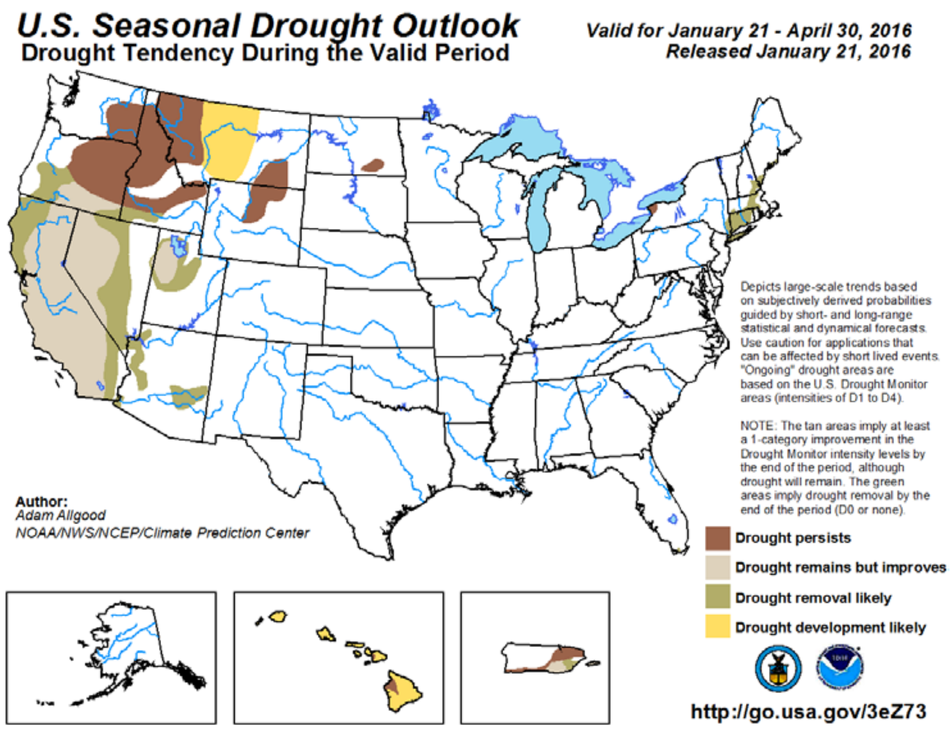


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

January precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). Precipitation amounts in the left image of Figure 4 generally ranged from 0.25 to 1.5 inches. The greatest amounts of January precipitation occurred in eastern Nebraska, southwest Iowa, eastern Kansas and Missouri. As a percent of normal in the right image of Figure 4, precipitation was generally below normal in the Upper Basin with some above normal areas including areas of northern Montana, a small area in southeast Montana, central Wyoming, eastern Nebraska and north central Kansas.

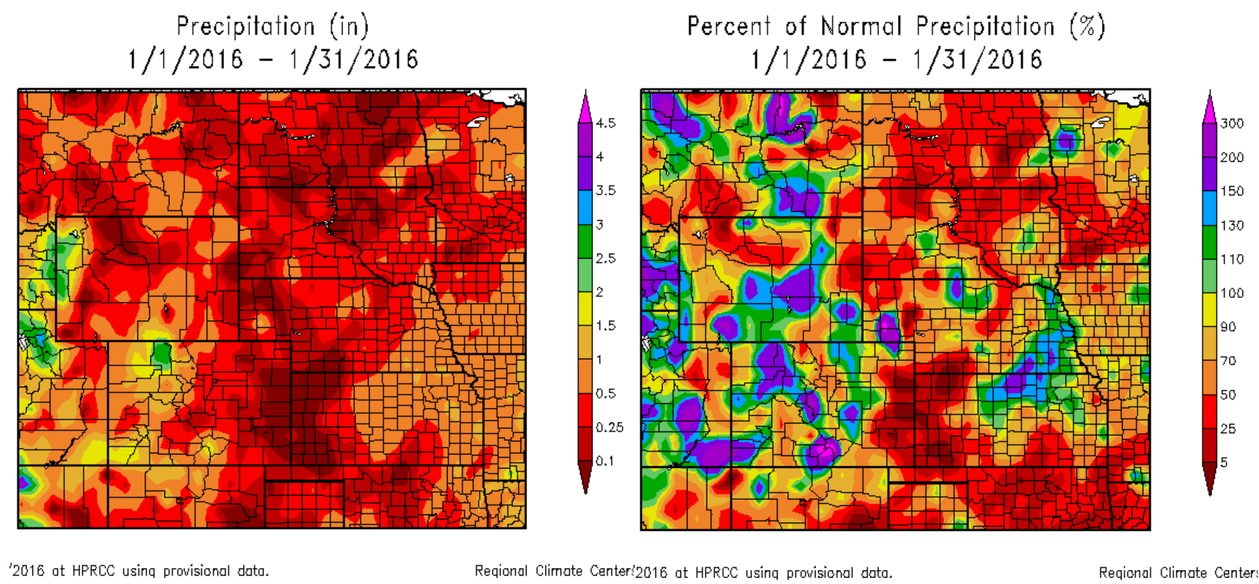


Figure 4. January 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

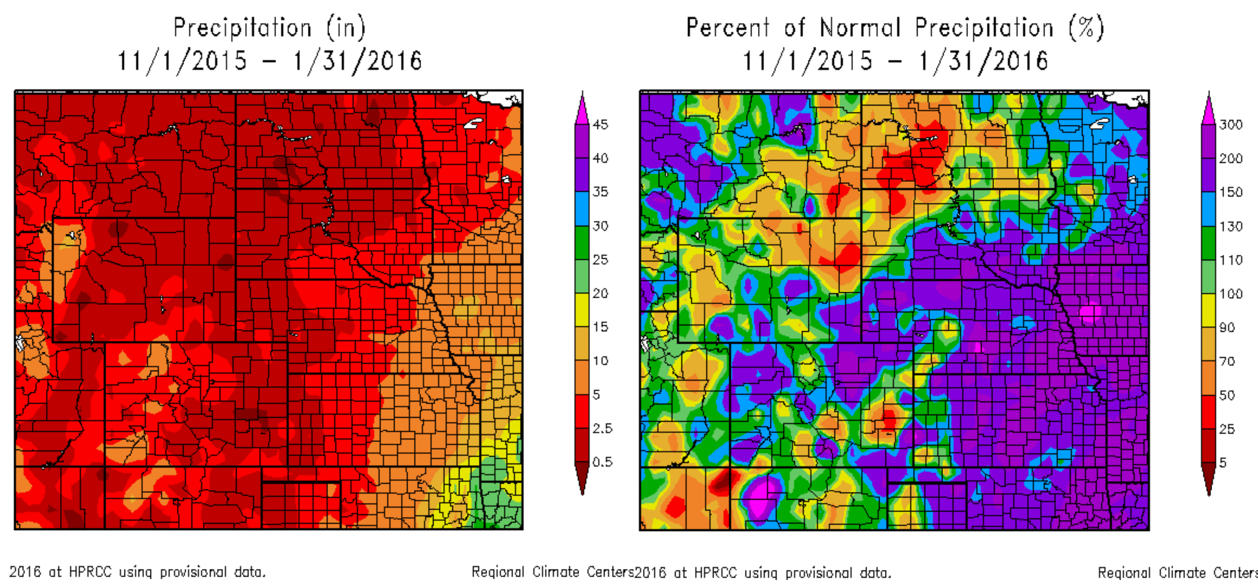


Figure 5. November-December 2015-January 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

November-December 2015-January 2016 precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a dry pattern in northeast Wyoming, southeastern and eastern Montana, western and central North Dakota, and northwestern South Dakota. In contrast, a wet or above normal precipitation pattern has been prevalent in western and north central Montana, and most of the Lower Basin, an area that has received greater than 150 percent of normal precipitation since November 1, 2015.

Temperature

January temperature departures from normal are shown in **Figure 6** in degrees Fahrenheit (deg F). January temperature departures in the Upper Basin were generally above normal ranging from 2 to 6 deg F. Temperatures were within 2 deg F of normal in southern South Dakota, the panhandle and eastern Nebraska, Iowa, eastern Kansas and Missouri. Temperatures were well below normal in the central Rocky Mountains of southern Wyoming and Colorado. Three-month (November-December-January) temperature departures are shown in **Figure 6**. The map indicates a very similar above normal pattern of temperatures across much of the Missouri Basin, particularly in the Northern Plains and Lower Basin. Temperatures have been near normal to slightly below normal in the Rocky Mountains.

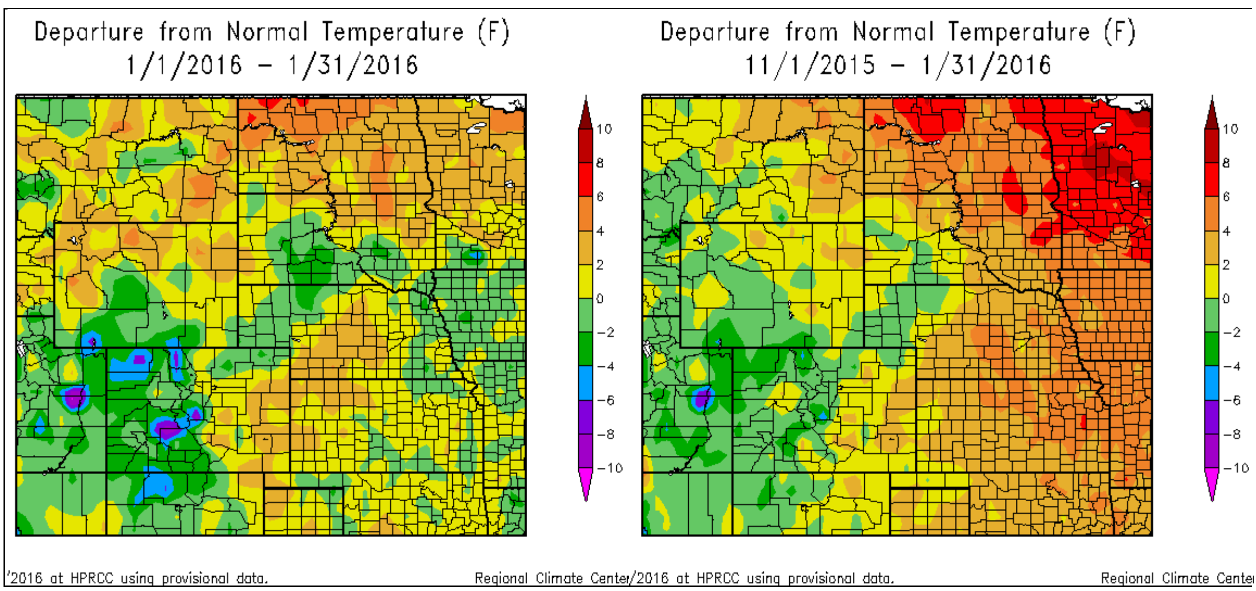


Figure 6. January 2016 and November-December 2015-January 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 mean soil moisture percentiles on January 29, 2016 for the top 1-meter of the modeled soil column. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above normal soil moisture conditions are present throughout much of the Upper Basin, though there are dry areas including north central Wyoming, eastern Montana, and eastern North Dakota. Wet soil moisture conditions (greater than 90th percentile moisture) are indicated in north central Montana, eastern Nebraska, and western Iowa.

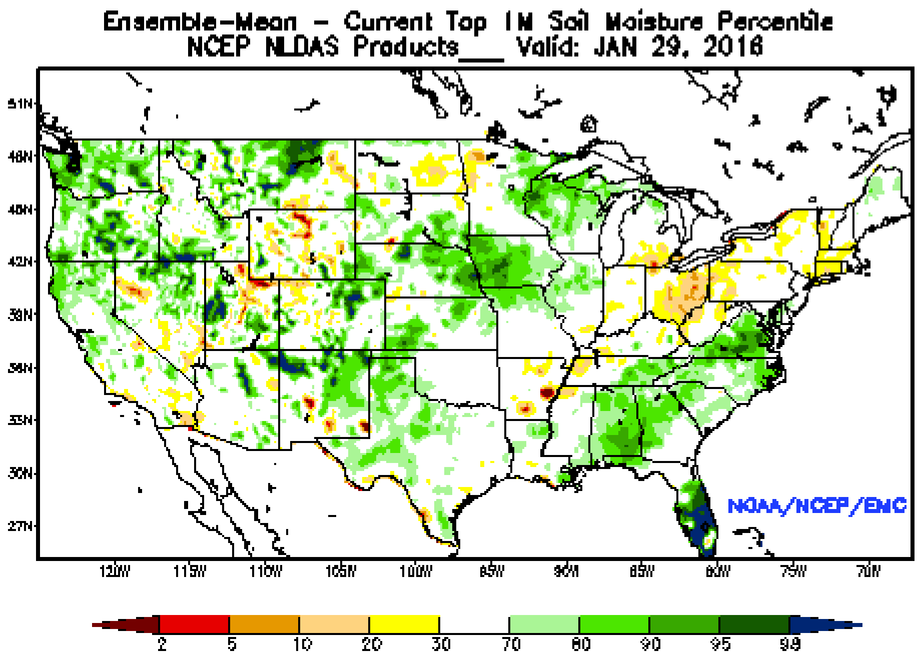


Figure 7. Top 1-Meter Soil Moisture Percentile on January 29, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Frost Conditions

Soil frost acts as a semi-impervious layer to snowmelt or precipitation infiltration into the soil. **Figure 8** shows depth of frost penetration at National Weather Service (NWS) Warning Forecast Office (WFO) locations in the Missouri Basin as of February 1, 2016. While some frost depth measurements are missing, measurements indicate soils are frozen at variable depths. Frost depths at Williston and Bismarck are 23 inches and 29 inches, respectively. In South Dakota reported depths are 16 inches at Rapid City and 24 inches at Aberdeen. In the Lower Basin, most depth measurements report as M (missing) or 0 inches.

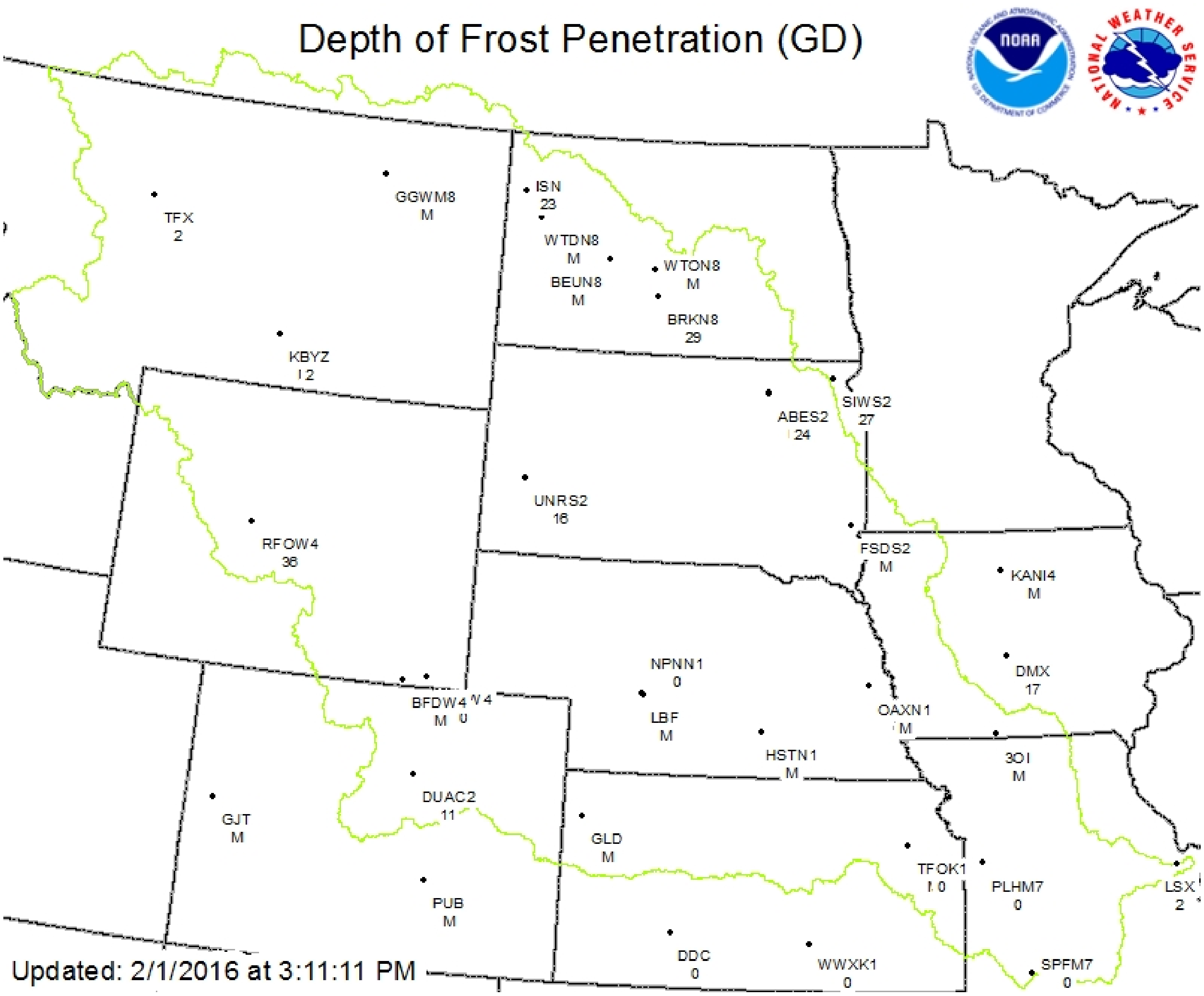


Figure 8. Measured frost depth (inches) at NWS WFO offices as of February 1, 2016. Source: NWS MBRFC. http://www.crh.noaa.gov/mbrfc

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 9**. These conditions are based on the ranking of the February 1, 2016 daily streamflow versus the historical record of streamflow for that date. Where streams are currently not influenced by ice formation along the mainstem of the Missouri River below Gavins Point Dam, streamflow conditions continue to be "Above normal" (76^{th} – 90^{th} percentile) or "Much above normal" (greater than the 90^{th} percentile). 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 in the Upper Basin that are reporting indicate streamflow conditions, particularly in Montana and Wyoming, are "Normal" (25th-75th percentile) to "Below normal" (10th-24th percentile).

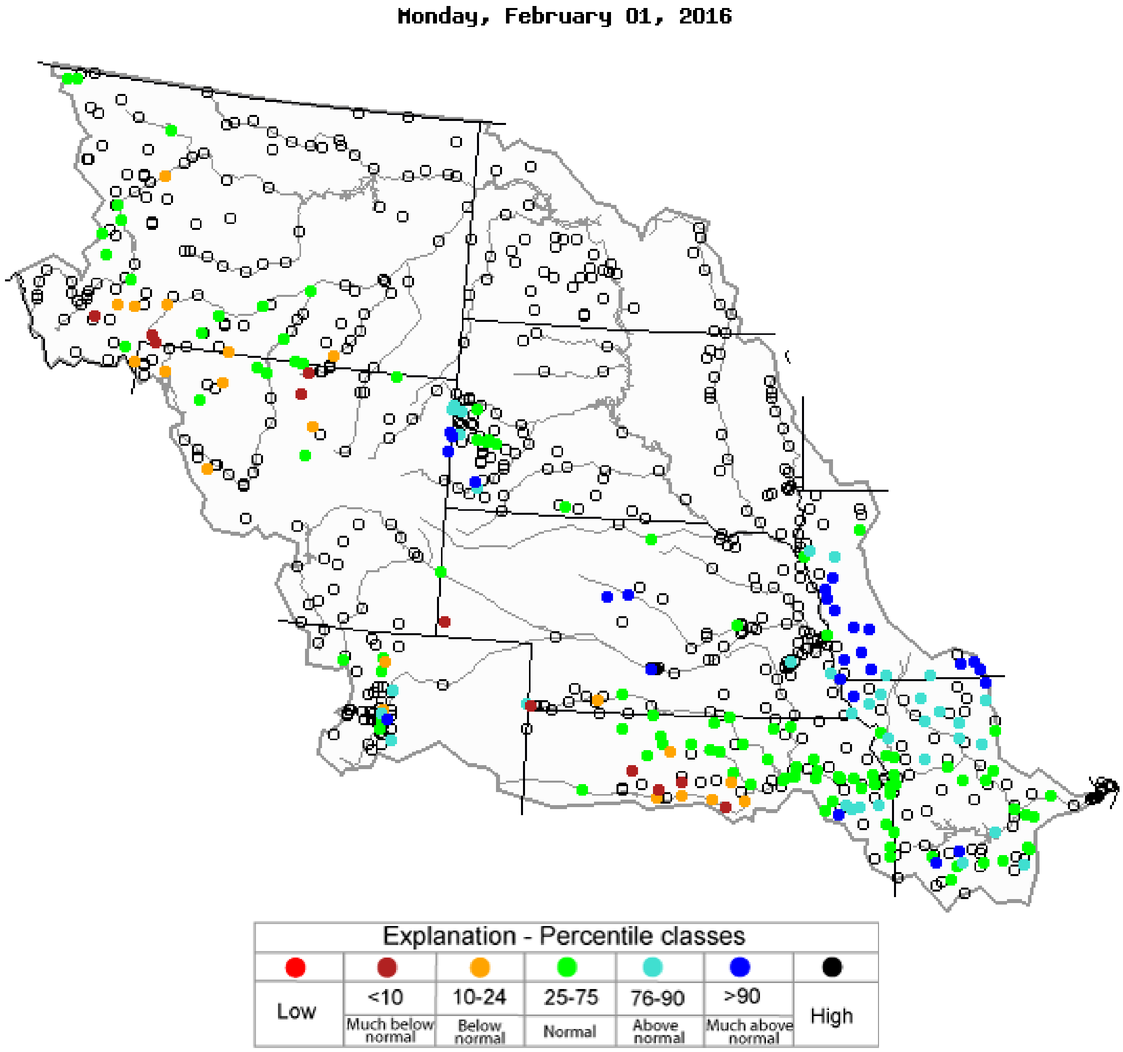


Figure 9. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of February 1, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

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.

Based on the National Operational Hydrologic Remote Sensing Center (NOHRSC) assessment (**Figure 10**) as of February 1, 2016 the only consistent snow cover remains in northeastern Montana, portions of central North Dakota, and eastern South Dakota. According to Corps cooperative snow observers, the remaining snow is very shallow, in drifts, or as standing water and ice in ditches. SWE measured by the observers in northeast Montana and the upper James River basin in North Dakota range from 1.0 to 1.5 inches.

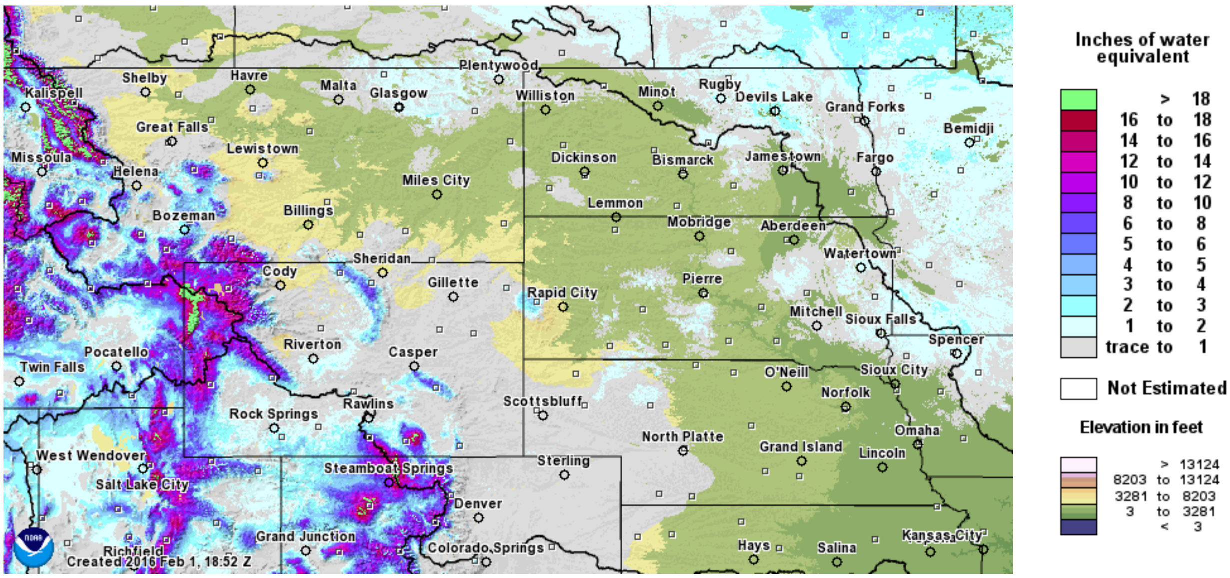


Figure 10. February 1, 2016 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Using the MRBWMD snowpack classification method, plains snowpack for the February 1, 2016 runoff forecast was classified according to the terminology listed in **Table 1**. A "Light" snowpack indicates snow cover that is above the median SWE, and a "Moderate" snowpack is greater than "Light". "Average" basin conditions indicate snowpack is less than "Light" with no measureable snow accumulations. March-April runoff in "Average" conditions is expected to be below or near long term average runoff. Runoff resulting from "Light" and "Moderate" snowpack accumulations is expected to be above long term average March-April runoff.

Table 1. Plains snowpack classification for the February 1, 2016 runoff forecast.

Reservoir Reach	Plains Snowpack Classification
Above Fort Peck	Average
Fort Peck to Garrison	Average
Garrison to Oahe	Average
Oahe to Fort Randall	Average
Fort Randall to Gavins Point	Average
Gavins Point to Sioux City	Average-Light

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.

Figure 11 includes time series plots of the average mountain SWE beginning on October 1, 2015 based on the NRCS SNOTEL gages for the 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), 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of **February 1, 2016**, the Corps of Engineers computed an average mountain SWE in the **Fort Peck reservoir reach of 9.5 inches, which is 92% 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 **6.3 inches, which is 72% of average** based on the 1981-2010 average SWE for the Garrison reach. Normally by February 1, 64% of the peak snow accumulation has occurred in the mountains.

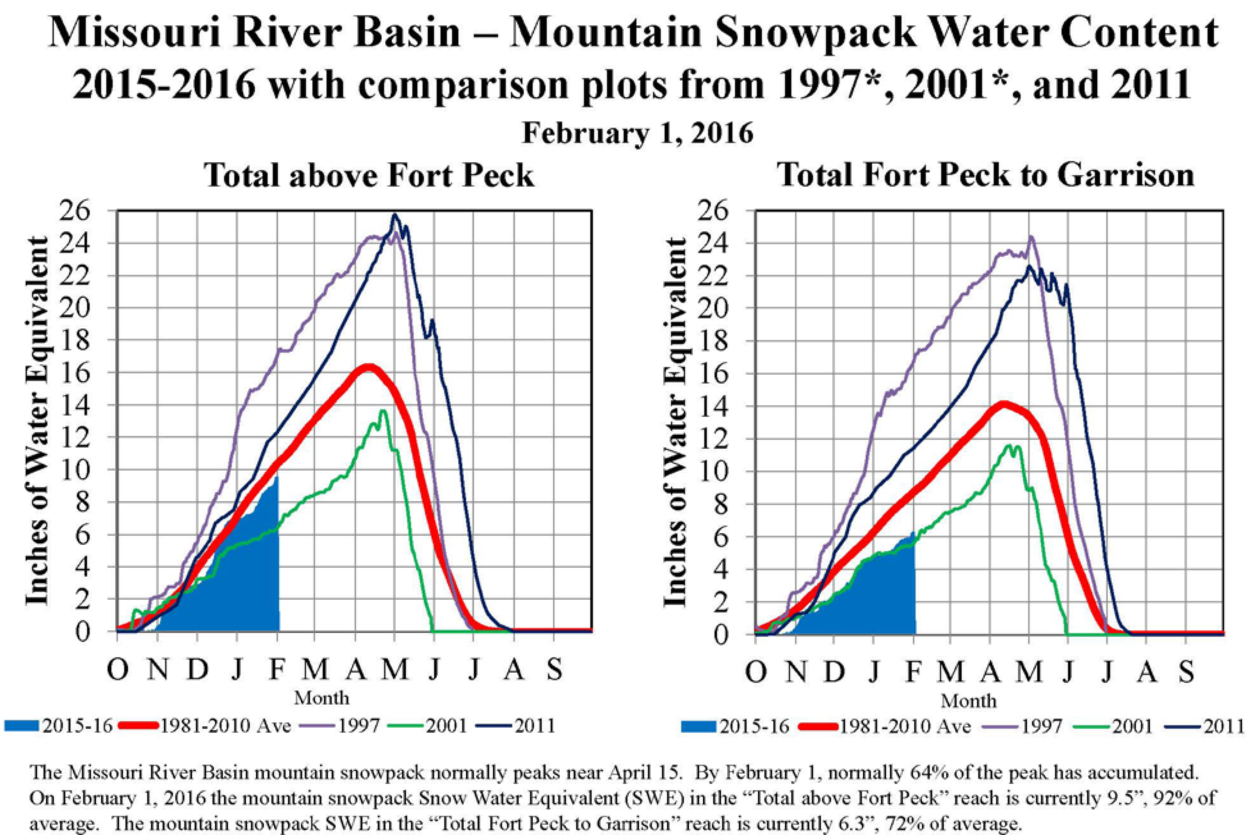


Figure 11. Mountain snowpack water content on February 1, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly update[1] on February 1, 2016, "***El Niño conditions are present. Positive equatorial sea surface temperature (SST) anomalies continue across most of the Pacific Ocean. A strong El Niño is expected to gradually weaken through spring 2016, and to transition to ENSO-neutral during late spring or early summer 2016***".

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 El Niño climate pattern and its implications on winter 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.

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

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for February 2016 (**Figure 12**) indicates an increased probability for above normal temperatures in Montana, North Dakota, South Dakota and northern Wyoming, and equal chances for below normal, normal and above normal temperatures over the remainder of the Missouri Basin. Probabilities for above normal temperatures range from a 50% chance temperatures will be above normal in northern Montana and northern North Dakota to a 33.3% to 40% chance in Wyoming and southern South Dakota. With regard to precipitation, there is greater than 40% chance precipitation will be below normal in much of Montana, and 33.3% to 40% chance for below normal precipitation in Wyoming and North Dakota. There are increased chances for above normal precipitation in Colorado, southeastern Wyoming, Nebraska, southern South Dakota, western Iowa, Kansas and northwestern Missouri.

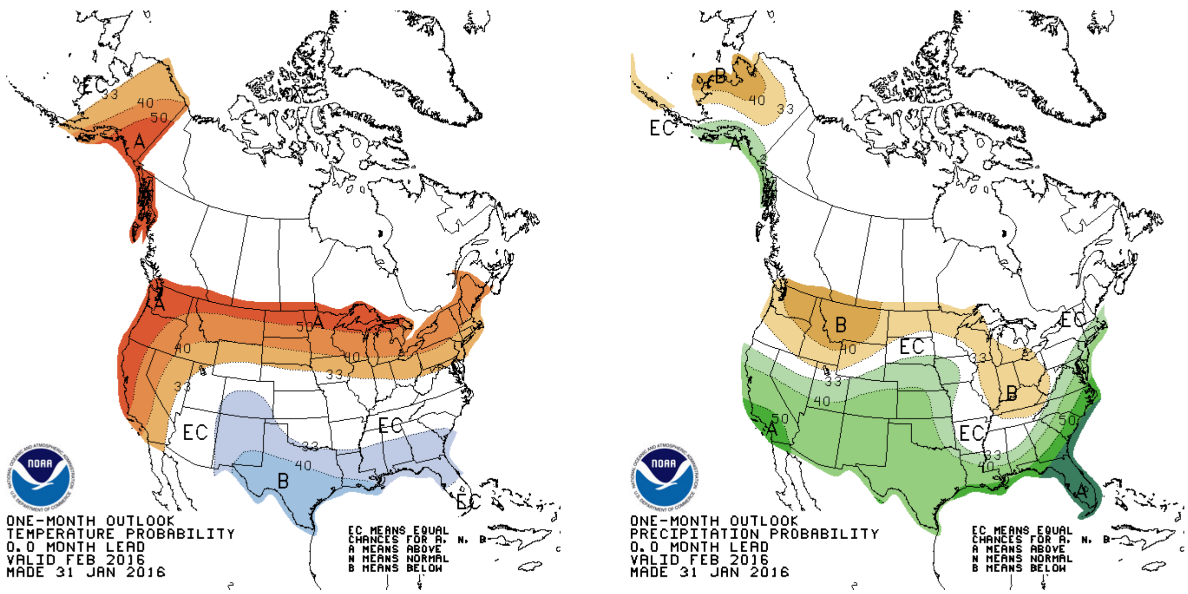


Figure 12. CPC February 2016 temperature and precipitation outlooks.

The February-March-April 2016 temperature outlook (**Figure 13**) indicates expanded areas of increased chances for above normal temperatures through the end of April. The February-March-April precipitation outlook indicates increased chances for below normal precipitation in northwestern Montana, equal chances for above normal, normal and below normal precipitation on the northern plains, and increased chances for above normal precipitation in southeastern Wyoming, Colorado, southern South Dakota, Nebraska and Kansas. The May-June-July 2016 CPC temperature outlook (**Figure 14**) indicates there are increased chances for above normal temperatures across much of the Missouri Basin. In terms of precipitation, there are increased chances for above normal precipitation in the central Rockies transitioning to equal chances in the Northern Rockies and plains.

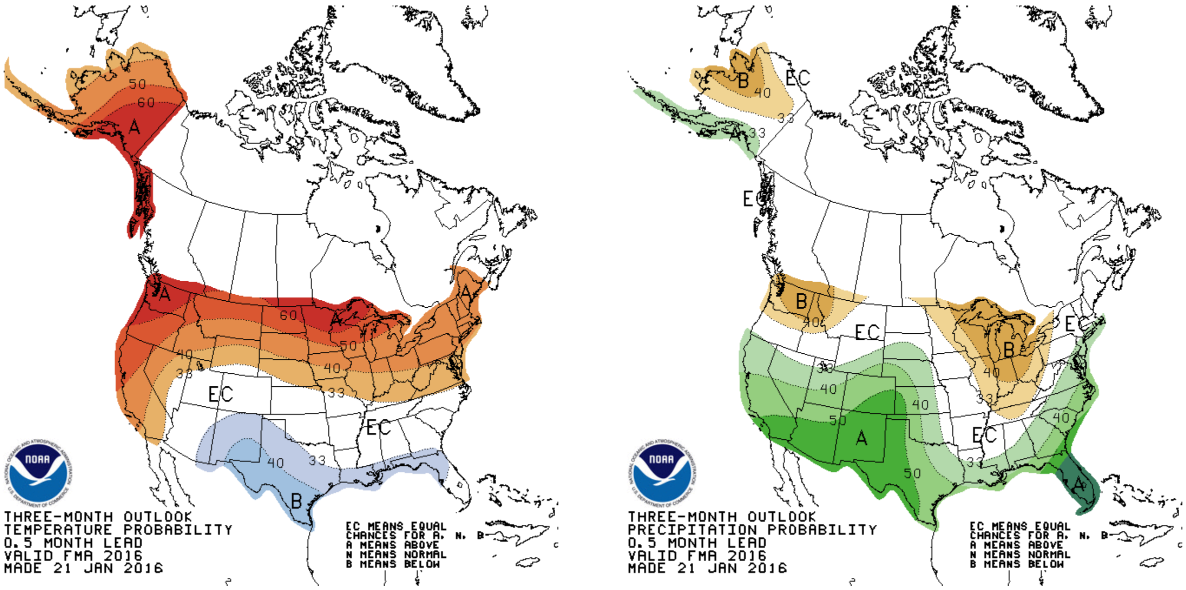


Figure 13. CPC February-March-April 2016 temperature and precipitation outlooks.

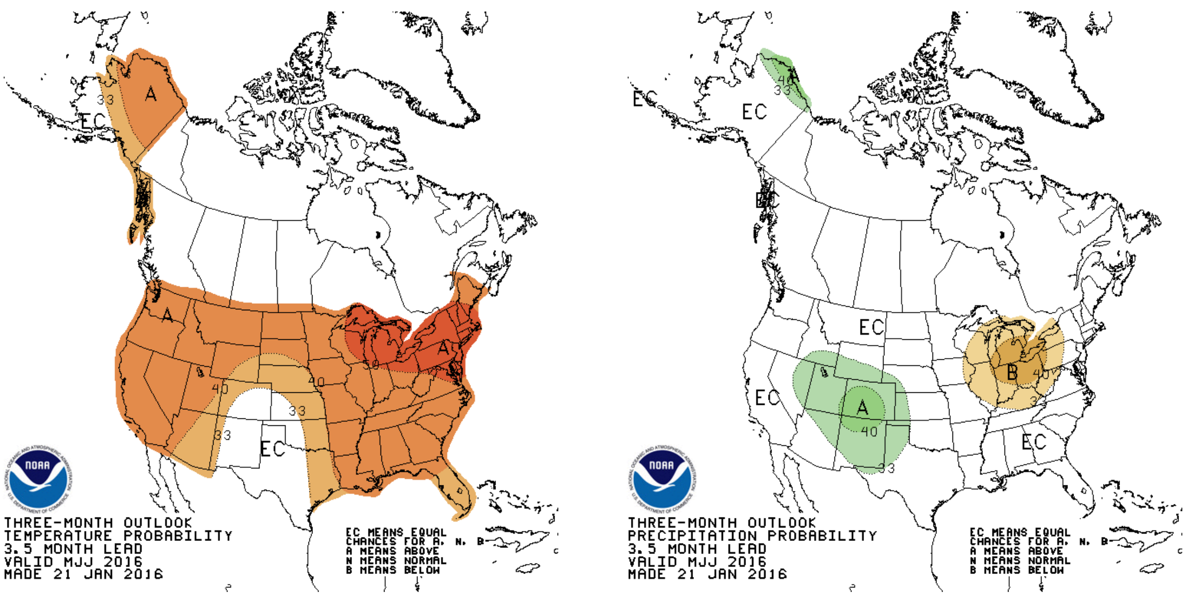


Figure 14. CPC May-June-July 2016 temperature and precipitation outlooks.

During the August-September-October 2016 period (**Figure 15**) CPC outlooks indicate increased chances for above normal temperatures across the entire Missouri Basin, and equal chances for above normal, normal and below normal precipitation. The November-December 2016-January 2017 period (**Figure 16**) outlook indicates increased chances for below normal temperatures in the Northern Rockies and plains. With regard to precipitation, the **Figure 18** outlook indicates there is an increased chance for above normal precipitation in the Northern Rockies and equal chances for much of the remaining Missouri Basin.

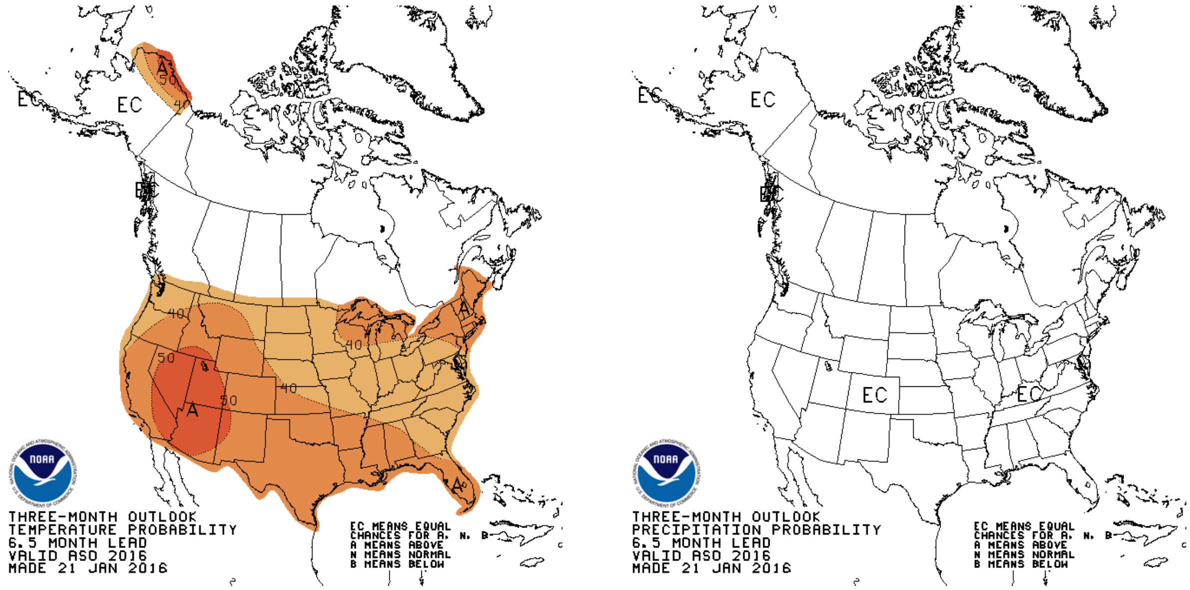


Figure 15. CPC August-September-October 2016 temperature and precipitation outlooks.

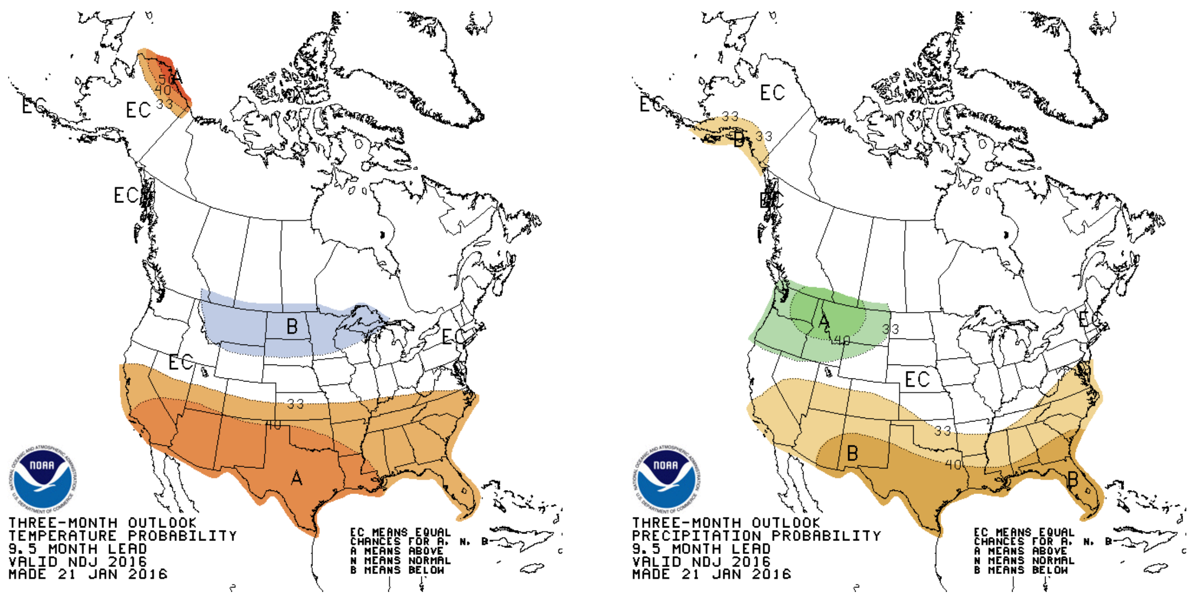
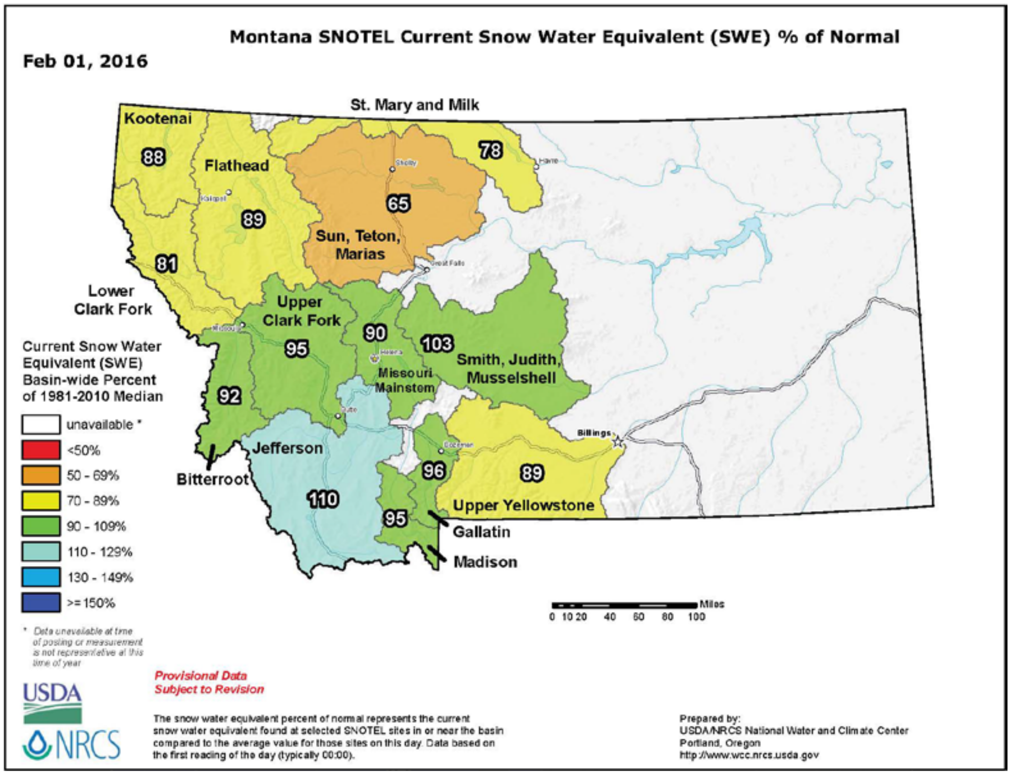


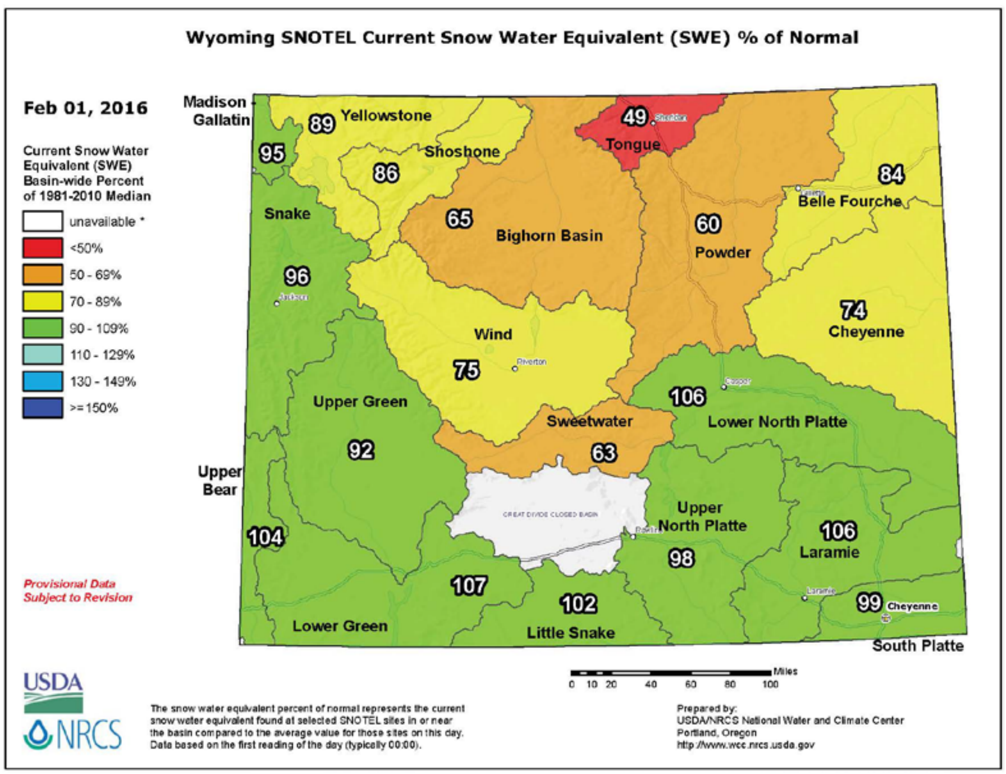
Figure 16. CPC November-December 2016-January 2017 temperature and precipitation outlooks.

February 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **23.3 MAF**, **92% of average**. Once again, we expect that the warmer-than-normal temperatures that are forecast over the next three months will lead to earlier-than-normal river ice breakup and plains snowmelt. Runoff is forecast to be about average in February and March; however, the lack of a consistent plains snowpack may lead to below average runoff in April. The below average mountain snowpack will likely lead to below average May-June-July runoff in the Fort Peck and Garrison reaches.

Additional Figures





USDA NRCS National Water & Climate Center
* - DATA CURRENT AS OF: February 03, 2016 06:26:55 PM
- Based on February 01, 2016 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	APR-JUL	84	87	99	90	78	69	97
	APR-SEP	98	88	113	104	92	83	112
St. Mary R at Int'l Boundary (2)	APR-JUL	360	83	460	400	320	260	435
	APR-SEP	415	82	515	455	375	315	505
Lima Reservoir Inflow (2)	APR-JUL	74	90	109	88	59	38	82
	APR-SEP	80	90	119	96	64	41	89
Clark Canyon Reservoir Inflow (2)	APR-JUL	85	84	146	110	61	25	101
	APR-SEP	105	88	175	133	77	36	120
Jefferson R nr Three Forks (2)	APR-JUL	740	100	1120	895	590	365	740
	APR-SEP	805	101	1230	975	635	385	800
Hebgen Reservoir Inflow (2)	APR-JUL	330	89	400	355	300	260	370
	APR-SEP	420	89	500	450	385	335	470
Ennis Reservoir Inflow (2)	APR-JUL	550	88	700	610	490	400	625
	APR-SEP	680	88	855	750	610	505	775
Missouri R at Toston (2)	APR-JUL	1680	94	2320	1940	1420	1030	1790
	APR-SEP	1920	93	2680	2230	1610	1160	2070
Smith R bl Eagle Ck (2)	APR-JUL	107	101	160	128	86	54	106
	APR-SEP	115	99	176	140	90	54	116
Gibson Reservoir Inflow (2)	APR-JUL	275	70	375	315	235	177	395
	APR-SEP	310	70	415	350	265	205	440
Marias R nr Shelby (2)	APR-JUL	205	59	385	275	133	54	345
	APR-SEP	210	58	400	285	134	52	360
Milk R at Western Crossing	MAR-SEP	27	82	54	38	18.9	11.8	33*

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	55	93	63	58	52	47	59
	APR-SEP	69	93	80	73	65	58	74
Wind R ab Bull Lake Ck (2)	APR-JUL	370	81	525	430	305	210	455
	APR-SEP	385	79	550	450	315	215	490
Bull Lake Ck nr Lenore	APR-JUL	108	78	141	121	94	74	139
	APR-SEP	130	77	171	146	114	89	169
Boysen Reservoir Inflow (2)	APR-JUL	365	60	725	510	215	2.0	610
	APR-SEP	375	56	755	530	220	2.0	665
Greybull R nr Meeteetse	APR-JUL	98	75	133	112	84	63	131
	APR-SEP	132	75	175	149	115	89	177
Shell Ck nr Shell	APR-JUL	33	60	49	40	27	17.8	55
	APR-SEP	42	64	59	49	35	26	66
Bighorn R at Kane (2)	APR-JUL	420	50	935	630	210	5.0	840
	APR-SEP	405	45	960	630	180	5.0	905
NF Shoshone R at Wapiti	APR-JUL	420	91	505	455	385	335	460
	APR-SEP	470	91	560	505	435	380	515
SF Shoshone R nr Valley	APR-JUL	195	91	235	210	178	153	215
	APR-SEP	220	90	270	240	205	175	245
Buffalo Bill Reservoir Inflow (2)	APR-JUL	610	90	755	670	555	470	675
	APR-SEP	665	89	815	725	605	515	745
Bighorn R nr St. Xavier (2)	APR-JUL	890	64	1510	1140	640	275	1380
	APR-SEP	870	60	1550	1150	595	193	1460
Little Bighorn R nr Hardin	APR-JUL	41	42	89	60	22	-6.9	98
	APR-SEP	47	42	100	68	26	-5.6	111

Tongue R nr Dayton (2)	APR-JUL	46	53	77	59	33	14.8	86
	APR-SEP	54	55	87	67	40	20	98
Tongue River Reservoir Inflow (2)	APR-JUL	94	49	200	137	51	5.0	193
	APR-SEP	106	49	220	151	61	5.0	215
NF Powder R nr Hazelton	APR-JUL	4.9	54	7.4	5.9	3.9	2.4	9.1
	APR-SEP	5.4	55	8.0	6.5	4.3	2.8	9.9
Powder R at Moorhead	APR-JUL	63	36	163	104	22	1.00	177
	APR-SEP	70	36	173	112	28	1.00	196
Powder R nr Locate	APR-JUL	78	39	235	142	15.3	1.00	199
	APR-SEP	85	39	250	152	18.7	1.00	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