Upper Missouri River Basin
April 2016 Calendar Year Runoff Forecast
April 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.

March 2016 Runoff

March 2016 Missouri River runoff was 1.8 MAF (60% of average) above Sioux City, IA (upper Basin). March 2016 runoff above Gavins Point Dam was 1.3 MAF (51% of average). Very little plains snowpack remained at the beginning of March due to earlier-than-normal snowmelt runoff that occurred in January and February. Furthermore, March precipitation was well-below average in the plains.

2016 Calendar Year Forecast Synopsis

The April 1 forecast for 2016 upper Basin runoff is **21.7 MAF** **(86% 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 9 months, the range of expected inflow is quite large and ranges from the 28.3 MAF upper basic forecast to the 15.9 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 9 months are being forecasted for this April 1 forecast (3 months observed/9 months forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all 6 reaches for 9 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 March 29, 2016 (**Figure 1**), when compared to the drought monitor for March 1, 2016 (**Figure 2**), shows an increase in areal extent of Abnormally Dry (D0) and Moderate Drought (D1) conditions in the upper Basin. Also there is additional development of Severe Drought (D2) conditions in southern Montana and northern Wyoming. In contrast, there has been a significant decrease of drought severity in western Montana. D1 and D2 conditions have been removed in most areas, with lingering D0 to D1 conditions in northwest Montana. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought will persist in western Montana. Drought conditions are likely to ease in south-central Montana, north-central Wyoming and eastern North Dakota through the end of June 2016.

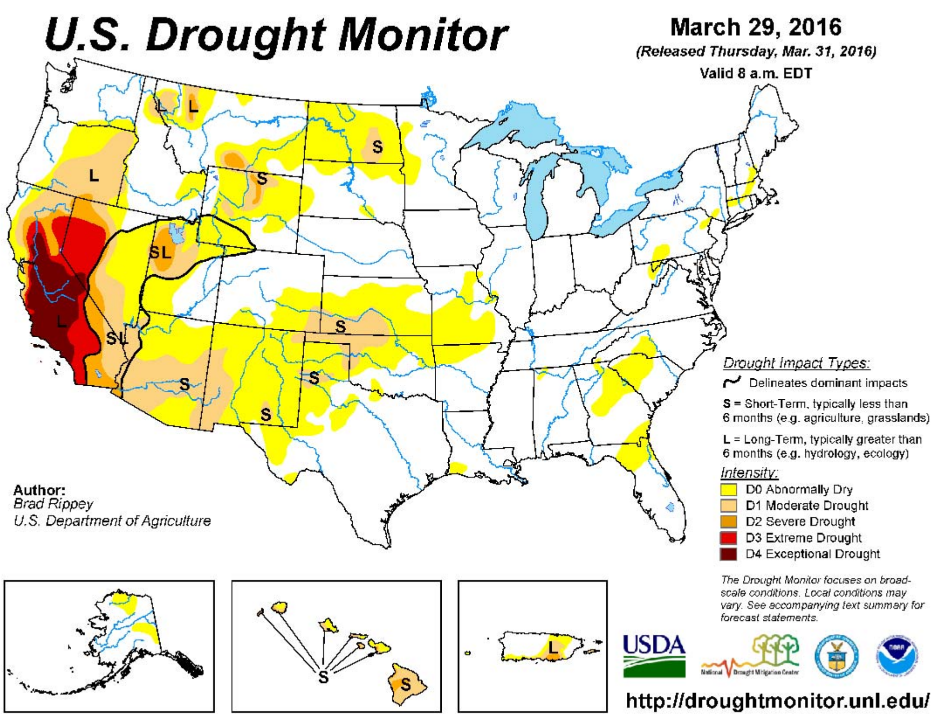


Figure 1 National Drought Mitigation Center U.S. Drought Monitor for March 29, 2016

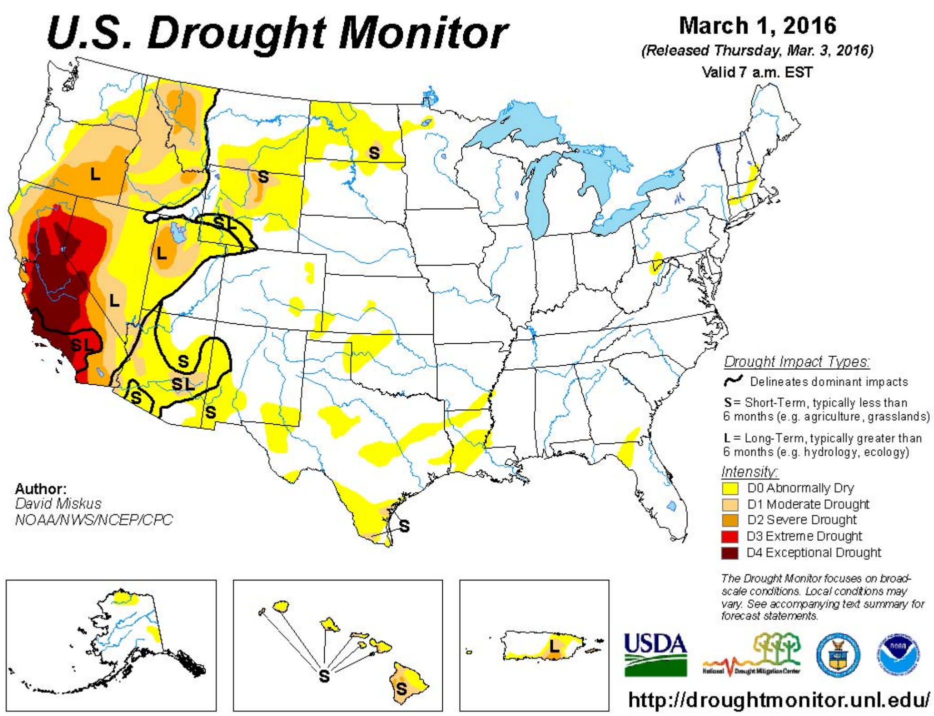


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for March 1, 2016.

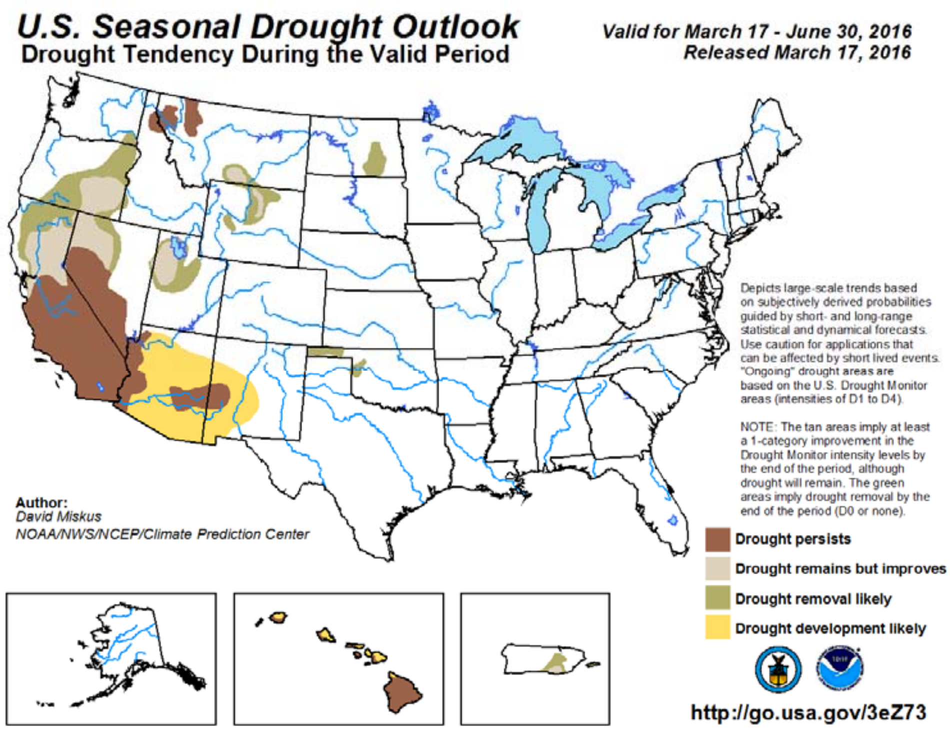


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

March precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). March precipitation was below normal from eastern Montana through the central and eastern Dakotas. Precipitation was also well-below normal in most of the lower Basin. Precipitation was more than 150% of normal in Wyoming, western Nebraska, and southwest South Dakota as a result of the winter storm that occurred at the end of March.

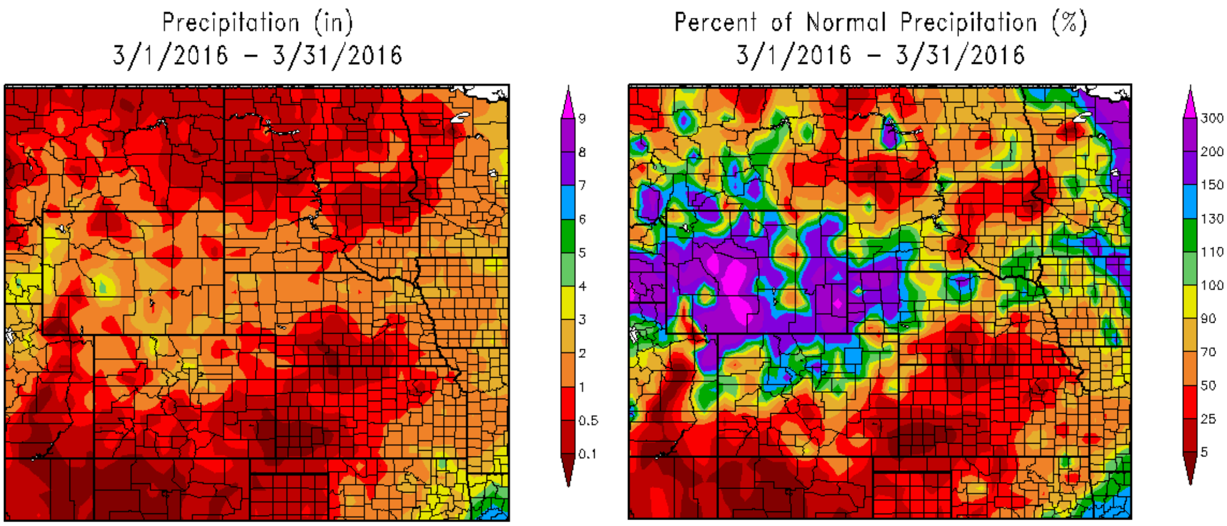


Figure 4. March 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 1 contains notable March precipitation and snowfall accumulations in these areas. Riverton, WY and Lander, WY received the greatest March precipitation accumulations due mainly to the end-of-March storm. Precipitation was also above normal at the other locations listed in **Table 1**. Snowfall totals were relatively heavy in Riverton and Lander; however, very little snowfall occurred in Billings, MT and Rapid City, SD.

Table 1. March 2016 snowfall and precipitation totals.

City, State	Snowfall inches	Precipitation inches	Precipitation Departure inches
Riverton, WY	21.5	2.13	1.58
Lander, WY	33.3	4.59	3.43
Worland, WY	m	0.97	0.51
Sheridan, WY	m	1.59	0.61
Billings, MT	1.9	1.55	0.49
Chadron, NE	m	2.44	1.21
Rapid City Arpt, SD	5.8	1.09	0.16

January-February-March 2016 precipitation accumulations are shown in **Figure 5**. The precipitation pattern since January 1 is similar to the March pattern, with the most notable above-normal accumulations in Wyoming, southern Montana and western Nebraska. The remainder of the upper Basin and much of the lower Basin was drier than normal from January through March.

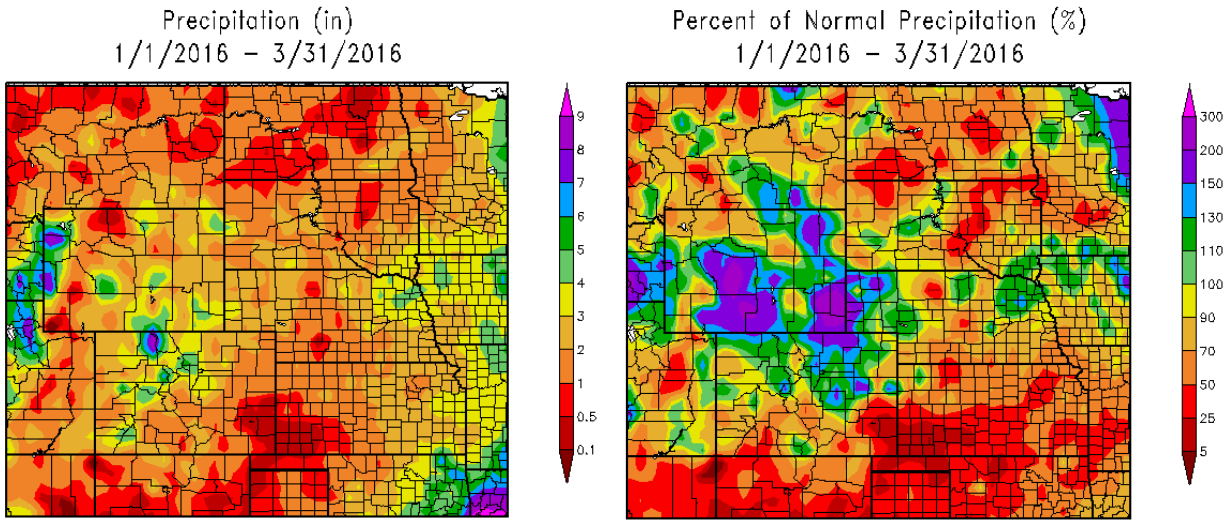


Figure 5. January-February-March 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

March temperature departures from normal are shown in **Figure 6** in degrees Fahrenheit (deg F). January-February-March 2016 temperature departures are also shown in **Figure 6**. Temperatures during March have ranged from near normal in the northern Rockies to more than 8 degrees F above normal in eastern North Dakota, with a similar pattern since January 1.

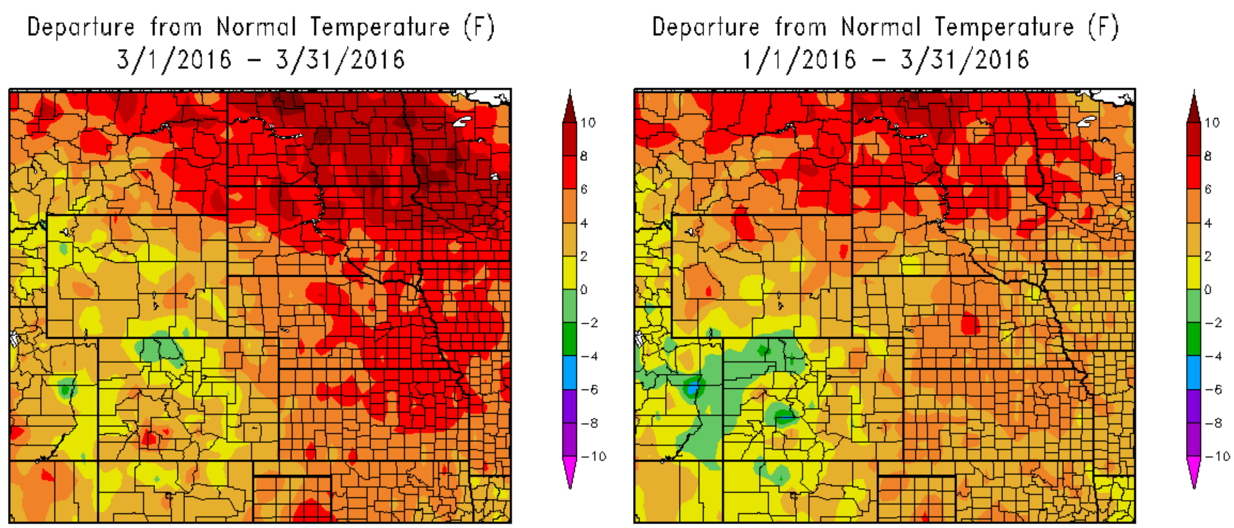


Figure 6. March 2016 and January-February-March 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 1-meter soil moisture anomaly on March 28, 2016. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above-normal soil moisture anomalies in north central and western Montana, western and southeastern South Dakota, western and eastern Nebraska, and western Iowa. Below-normal soil moisture anomalies are present in south central Montana and north central Wyoming, North Dakota, and northern South Dakota.

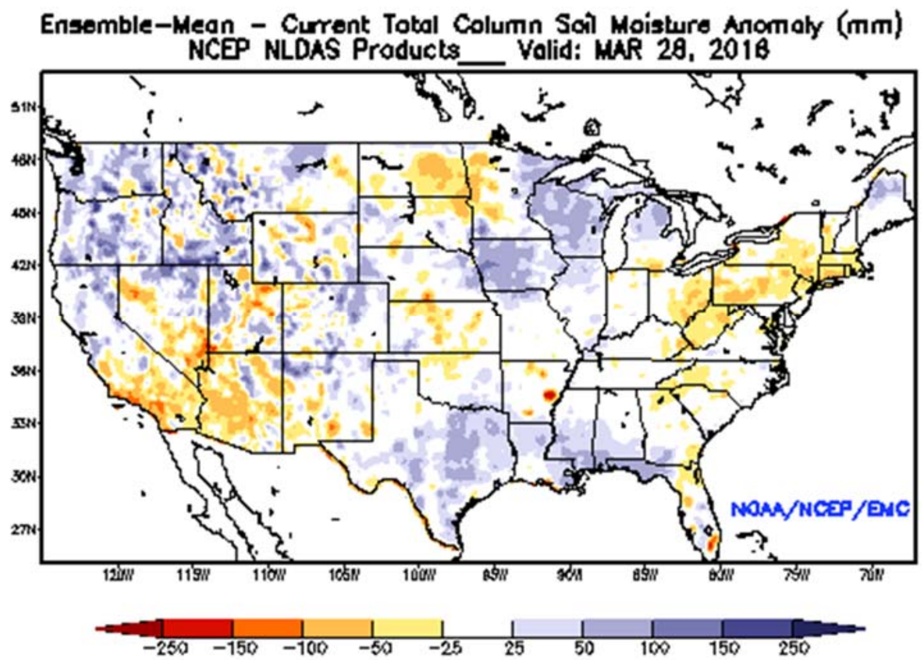


Figure 7. Top 1-Meter Soil Moisture Anomaly on March 28, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

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 March 31, 2016. At this time, the soil moisture map indicates there is no soil frost in the Basin at the locations where it is measured.

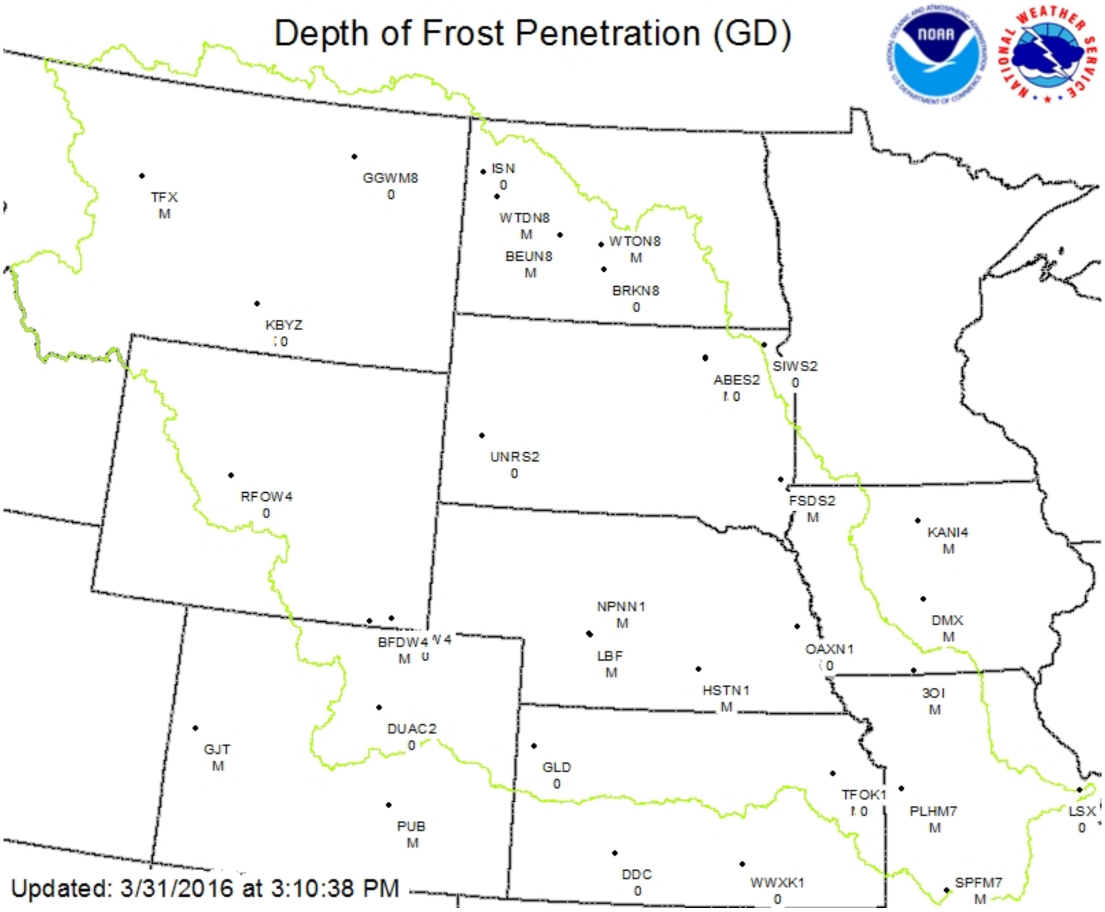


Figure 8. Measured frost depth (inches) at NWS WFO offices as of March 31, 2016. Source: NWS MBRFC. http://www.crh.noaa.gov/mbrfc

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 9**. These conditions are based on the ranking of the April 2, 2016 daily streamflow versus the historical record of streamflow for that date. All river ice has melted, therefore, streamflow conditions are no longer ice-affected. Streamflow conditions range from “Normal” (25^{th}-75^{th} percentile) to “Below normal” (10^{th}-24^{th} percentile) over a majority of the upper Basin and the lower Basin below Nebraska City. Streamflow conditions are “Normal” to “Above normal” (76^{th} – 90^{th} percentile) in the Black Hills and the Basin from Fort Randall Dam to Nebraska City, NE. A number of stations in these areas are “Above Normal” (76^{th} – 90^{th} percentile).

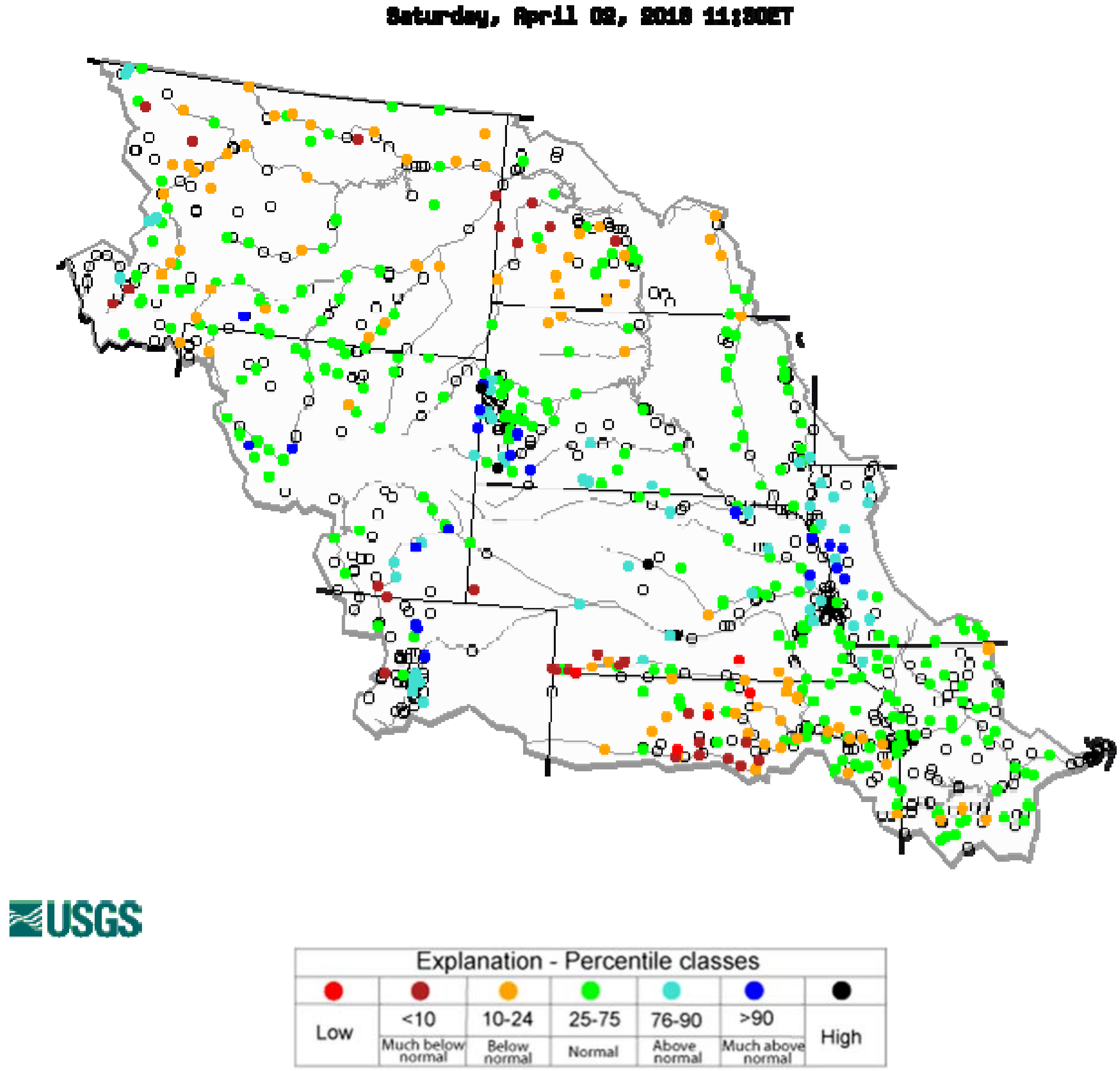


Figure 9. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of April 2, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

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 April 4, 2016, there is currently no plains snowpack. Much of the seasonal plains snowpack had melted by mid-February. Since March 1, additional snowfall has resulted in only short-term accumulations.

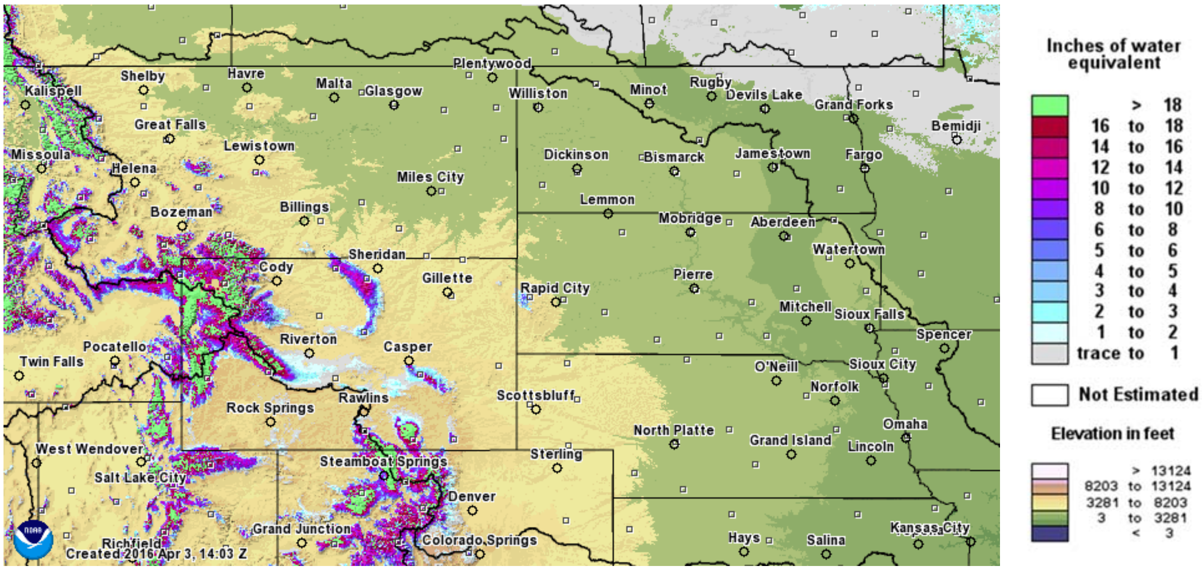


Figure 10. April 4, 2016 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

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 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 below-average runoff from a below-average mountain snowpack this year due to soil moisture conditions ranging from drier than normal to wetter than normal.

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).

The mountain snow water equivalent (or SWE) has made significant gains over the past month. On February 29 mountain SWE was 11.5 inches (89% of average) in the reach above Fort Peck and 8.2 inches (75% of average) from Fort Peck to Garrison. As of April 1, mountain SWE was 15.0 inches (95% of average) above Fort Peck and 12.2 inches (89% of average) from Fort Peck to Garrison. The gain in mountain SWE results in an increase in the runoff forecast for Fort Peck and Garrison during the May-June-July period, when runoff from mountain snowmelt occurs. On average, about 97% of the SWE has accumulated by April 1, and mountain snowpack normally peaks around April 15.

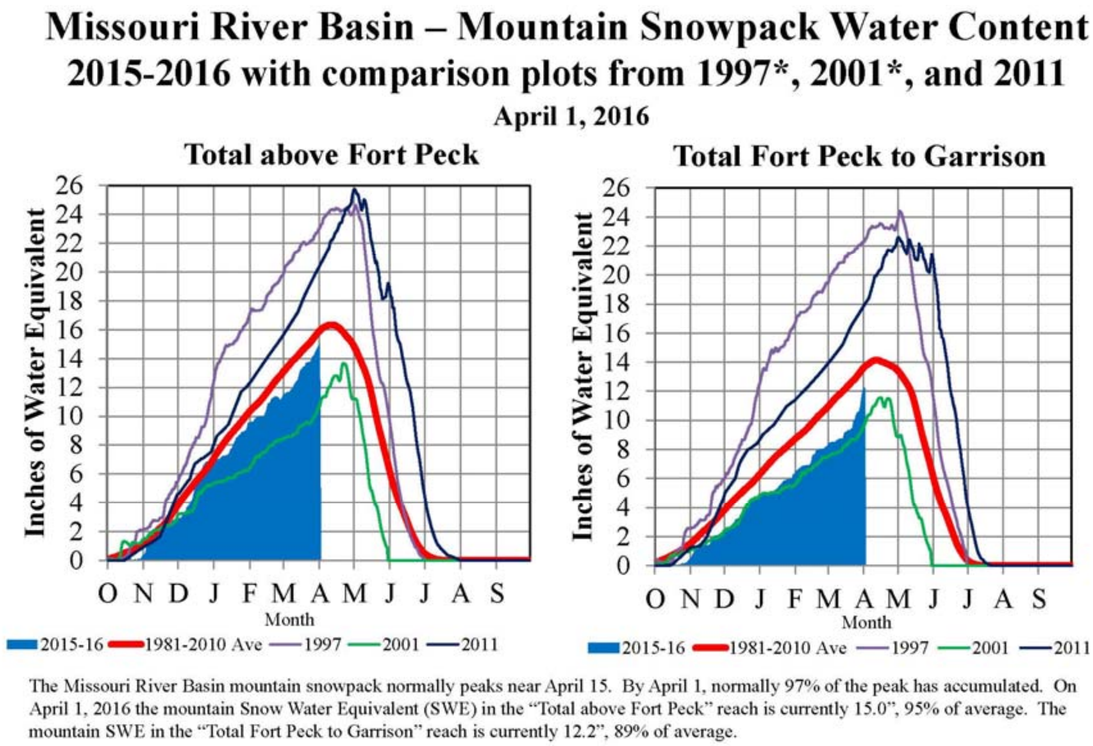


Figure 11. Mountain snowpack water content on April 1, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly update[1] on April 4, 2016, "***A strong El Niño is present and is weakening. A transition to ENSO-neutral is likely during late Northern Hemisphere spring or early summer 2016, with close to a 50% chance for La Niña conditions to develop by the fall.***"

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 April 2016 (**Figure 12)** indicates that above-normal temperatures will occur over the Basin in April. Probabilities for above-normal temperatures range from 33% chance temperatures will be above normal in the eastern Dakotas to greater than 60% chances in western Montana and western Wyoming. With regard to precipitation, there are increased chances (33% to greater than 40%) that below-normal precipitation will occur in the Northern Plains, equal chances from Montana into Nebraska, and above-normal chances (33% to greater than 40%) in the central Rockies.

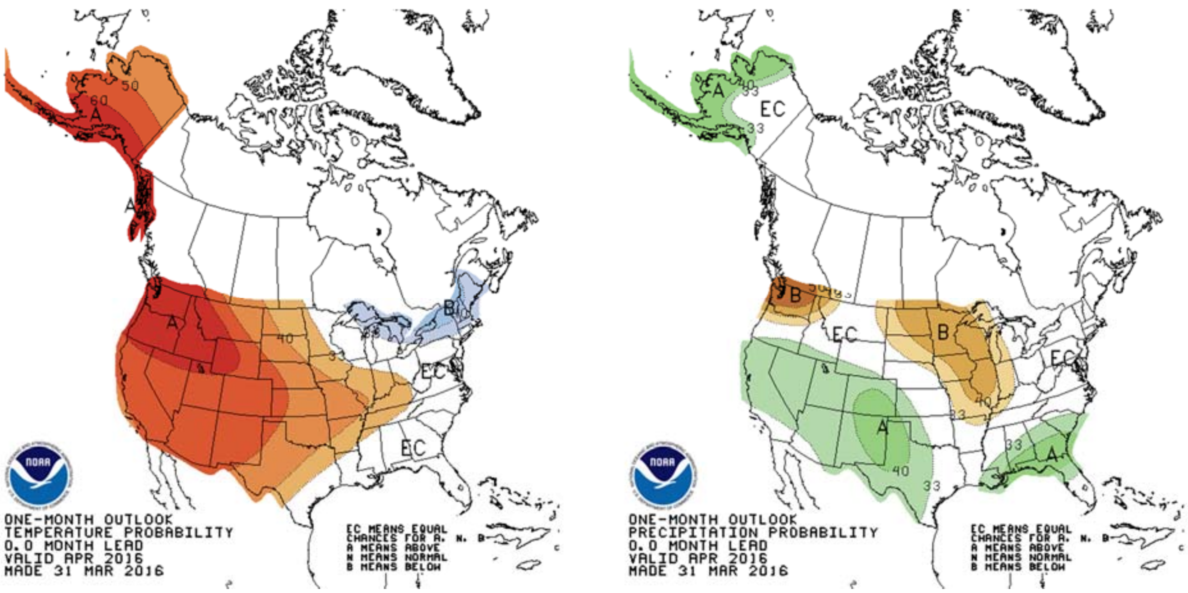


Figure 12. CPC April 2016 temperature and precipitation outlooks.

The April-May-June 2016 temperature outlook (**Figure 13**) indicates there are increased chances (33% to greater than 50%) for above-normal temperatures over the upper Basin, and equal chances in the lower Basin. With regard to precipitation, the April-May-June outlook indicates there are equal chances over most of the upper Basin, and increased chances (33% to greater than 40%) for above-normal precipitation in much of Wyoming and the central Rockies. The July-August-September 2016 CPC temperature outlook (**Figure 14**) indicates there are increased chances (33% to greater than 40%) for above-normal temperatures across the entire Missouri Basin. In terms of precipitation, there are equal chances for above- and below-normal precipitation throughout the entire Basin during July-August-September.

During the October-November-December 2016 period (**Figure 15**) CPC outlooks indicate increased chances (33% to greater than 40%) for above-normal temperatures in Wyoming, southern South Dakota, Nebraska, Iowa and the remaining lower Basin. There are equal chances for above-normal, normal and below-normal temperatures in Montana, North Dakota, and the northern half of South Dakota. With regard to precipitation, the October-November-December outlook indicates there are increased chances (33% to greater than 40%) for above-normal precipitation in western and central Montana, and equal chances elsewhere in the Basin. The increased chances for above-normal precipitation in Montana during October-November-December are a reflection of the possible impact that a La Niña ENSO pattern could have on the upper Basin climate.

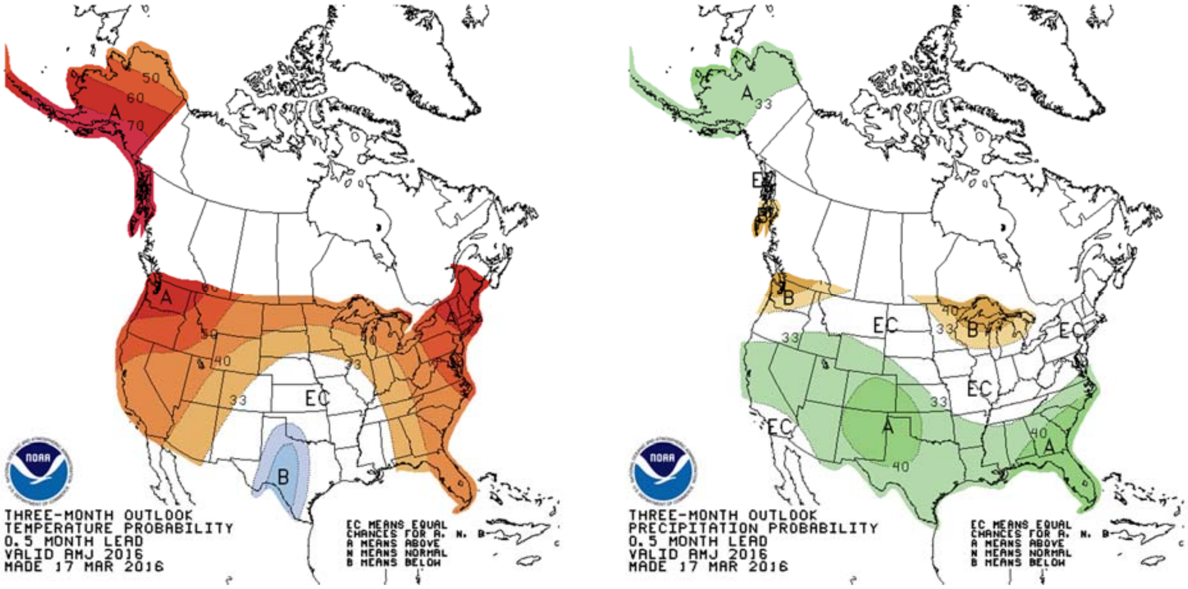


Figure 13. CPC April-May-June 2016 temperature and precipitation outlooks.

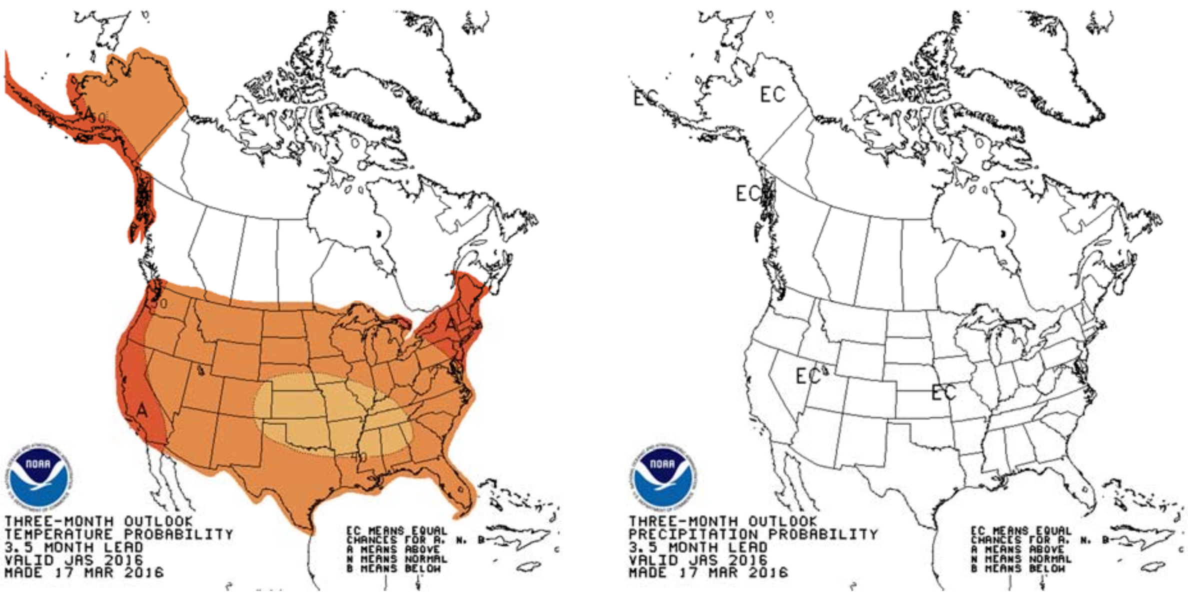


Figure 14. CPC July-August-September 2016 temperature and precipitation outlooks.

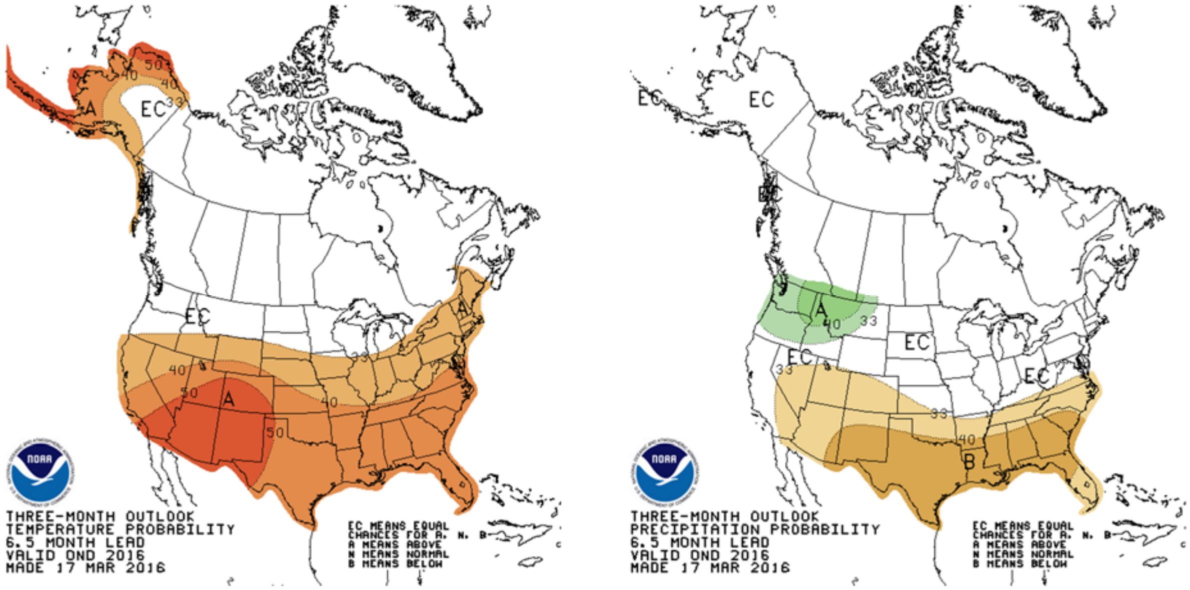
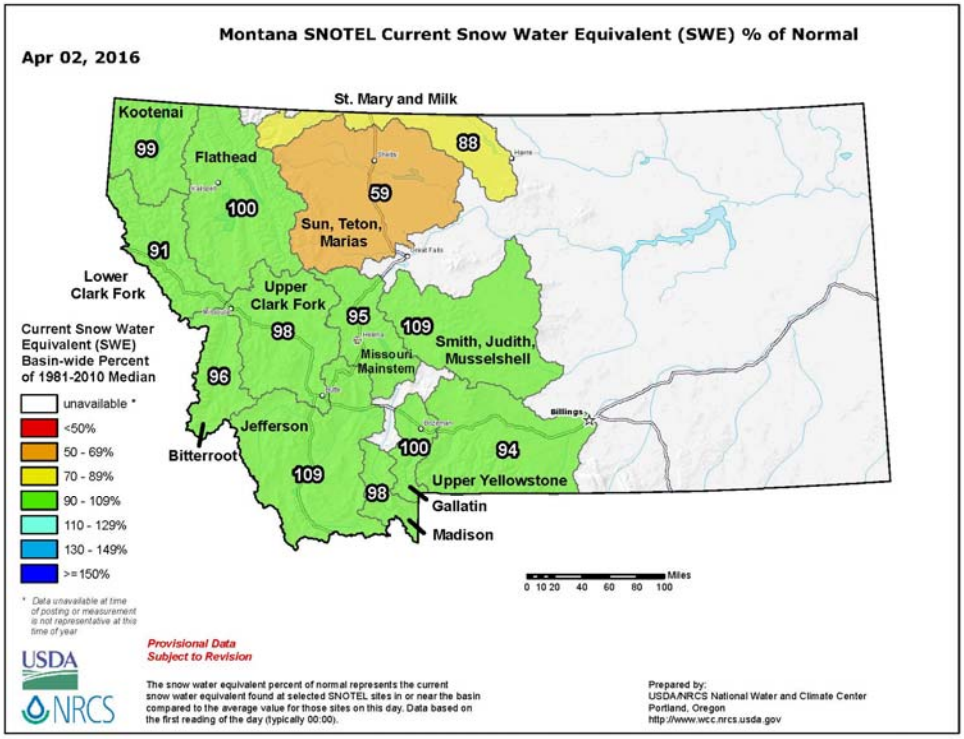


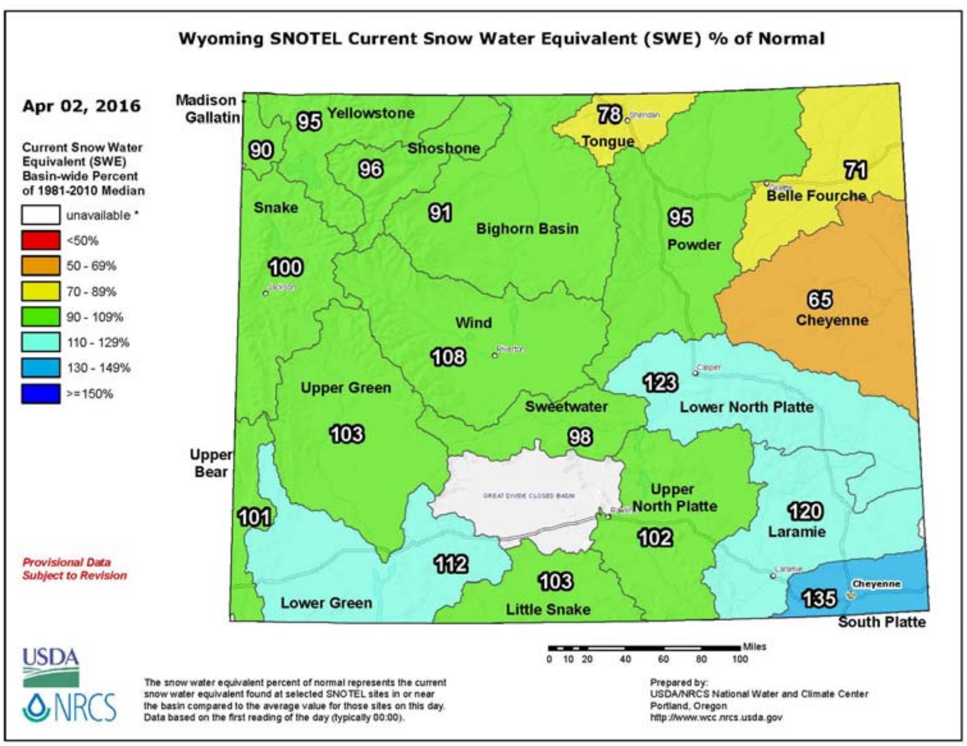
Figure 15. CPC October-November-December 2016 temperature and precipitation outlooks.

April 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **21.7 MAF**, **86% 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)**. Although runoff is forecast to be well-below normal in the plains during the next two months, gains in mountain snowpack has increased the May-June-July runoff forecast. We will continue to monitor Basin conditions and make forecast adjustments as conditions change.

Additional Figures





USDA NRCS National Water & Climate Center
 * - DATA CURRENT AS OF: April 04, 2016 05:49:53 PM
   - Based on April 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	92	95	106	98	86	78	97
	APR-SEP	106	95	122	113	99	90	112
St. Mary R at Int'l Boundary (2)	APR-JUL	410	94	505	450	370	315	435
	APR-SEP	470	93	570	510	430	370	505
Lima Reservoir Inflow (2)	APR-JUL	75	91	92	82	68	58	82
	APR-SEP	81	91	101	89	73	61	89
Clark Canyon Reservoir Inflow (2)	APR-JUL	96	95	163	123	69	29	101
	APR-SEP	117	98	188	146	88	46	120
Jefferson R nr Three Forks (2)	APR-JUL	815	110	1160	955	675	475	740
	APR-SEP	875	109	1250	1030	720	490	800
Hebgen Reservoir Inflow (2)	APR-JUL	330	89	380	350	310	280	370
	APR-SEP	420	89	480	445	395	360	470
Ennis Reservoir Inflow (2)	APR-JUL	595	95	710	640	545	475	625
	APR-SEP	735	95	870	790	680	600	775
Missouri R at Toston (2)	APR-JUL	1820	102	2380	2050	1590	1250	1790
	APR-SEP	2090	101	2780	2370	1810	1400	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	240	61	320	275	205	158	395
	APR-SEP	270	61	360	305	230	178	440
Marias R nr Shelby (2)	APR-JUL	176	51	340	240	110	12.3	345
	APR-SEP	182	51	360	255	109	10.4	360

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	56	95	63	59	53	49	59
	APR-SEP	71	96	82	75	67	60	74
Wind R ab Bull Lake Ck (2)	APR-JUL	470	103	565	510	430	375	455
	APR-SEP	500	102	615	545	455	385	490
Bull Lake Ck nr Lenore	APR-JUL	151	109	187	166	136	115	139
	APR-SEP	183	108	230	200	164	137	169
Boysen Reservoir Inflow (2)	APR-JUL	675	111	1010	810	540	340	610
	APR-SEP	730	110	1100	880	580	360	665
Greybull R nr Meeteetse	APR-JUL	140	107	184	158	122	96	131
	APR-SEP	190	107	245	210	168	136	177
Shell Ck nr Shell	APR-JUL	40	73	54	46	34	25	55
	APR-SEP	51	77	68	58	45	35	66
Bighorn R at Kane (2)	APR-JUL	870	104	1390	1080	660	350	840
	APR-SEP	940	104	1510	1170	710	370	905
NF Shoshone R at Wapiti	APR-JUL	450	98	525	480	420	375	460
	APR-SEP	505	98	590	540	470	415	515
SF Shoshone R nr Valley	APR-JUL	225	105	260	240	210	188	215
	APR-SEP	260	106	305	280	240	215	245
Buffalo Bill Reservoir Inflow (2)	APR-JUL	700	104	835	755	645	565	675
	APR-SEP	770	103	930	835	705	610	745
Bighorn R nr St. Xavier (2)	APR-JUL	1420	103	2030	1670	1170	810	1380
	APR-SEP	1500	103	2200	1780	1220	800	1460
Little Bighorn R nr Hardin	APR-JUL	52	53	94	69	35	10.3	98
	APR-SEP	61	55	107	80	42	15.0	111

Tongue R nr Dayton (2)	APR-JUL	53	62	80	64	42	26	86
	APR-SEP	63	64	93	75	51	33	98
Tongue River Reservoir Inflow (2)	APR-JUL	124	64	225	164	84	25	193
	APR-SEP	140	65	245	182	98	35	215
NF Powder R nr Hazelton	APR-JUL	7.4	81	9.8	8.4	6.4	5.0	9.1
	APR-SEP	8.0	81	10.6	9.1	6.9	5.4	9.9
Powder R at Moorhead	APR-JUL	137	77	250	184	90	22	177
	APR-SEP	151	77	270	199	103	32	196
Powder R nr Locate	APR-JUL	156	78	295	210	100	17.6	199
	APR-SEP	170	77	320	230	110	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