Upper Missouri River Basin
May 2016 Calendar Year Runoff Forecast
May 6, 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.

April 2016 Runoff

April 2016 Missouri River runoff was 2.6 MAF (90% of average) above Sioux City, IA (upper Basin). March 2016 runoff above Gavins Point Dam was 2.2 MAF (86% of average). April runoff was 90% of average above Sioux City, IA, with inflows above Oahe Dam at 69% of average and inflows from Oahe Dam to Sioux City at 153% of average. Runoff was well below average during the first half of April due to lack of rainfall and a lack of plains snowpack coupled with an earlier than normal snowmelt in January and February. Significant rainfall events resulted in runoff being average to much above average throughout the basin during the last half of April.

2016 Calendar Year Forecast Synopsis

The May 1 forecast for 2016 upper Basin runoff is **22.5 MAF (89% of average)**. Runoff for the basin above Gavins Point Dam is forecast to be **19.7 MAF (85% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 8 months, the range of expected inflow is quite large and ranges from the 28.2 MAF upper basic forecast to the 17.4 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 8 months are being forecasted for this May 1 forecast (4 months observed/8 months forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all 6 reaches for 8 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 April 26, 2016 (**Figure 1**), when compared to the drought monitor for March 29, 2016 (**Figure 2**), shows a decrease in areal extent of Abnormally Dry (D0) and Moderate Drought (D1) conditions in the upper Basin with an increase of D0 and D1 conditions in portions of Missouri. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought is expected to ease in Montana, Wyoming, North Dakota, South Dakota, Kansas and Missouri through the end of July 2016.

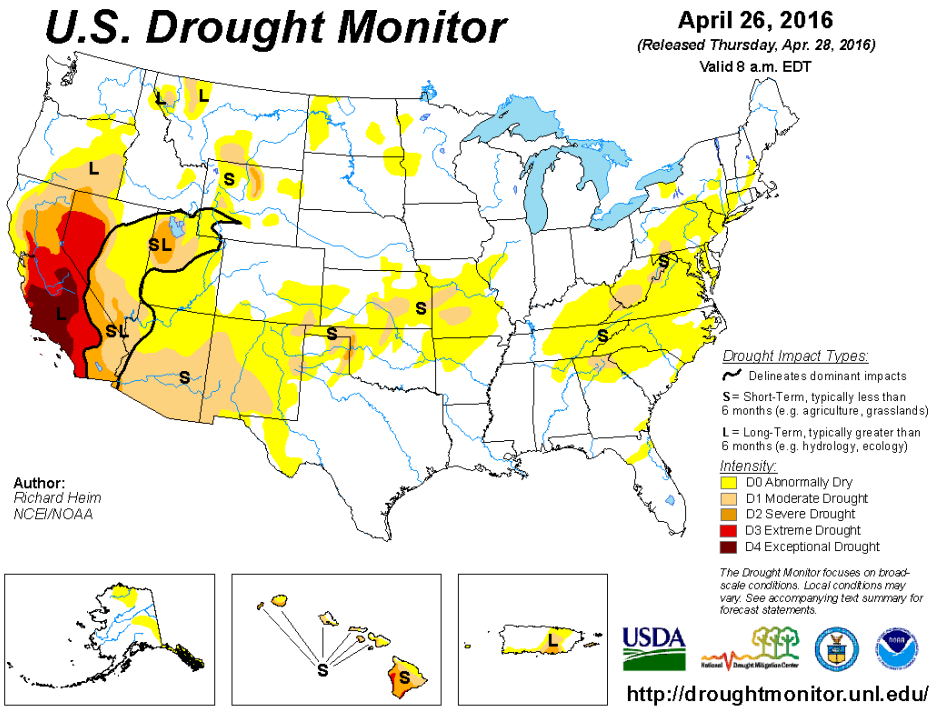


Figure 1 National Drought Mitigation Center U.S. Drought Monitor for April 26, 2016

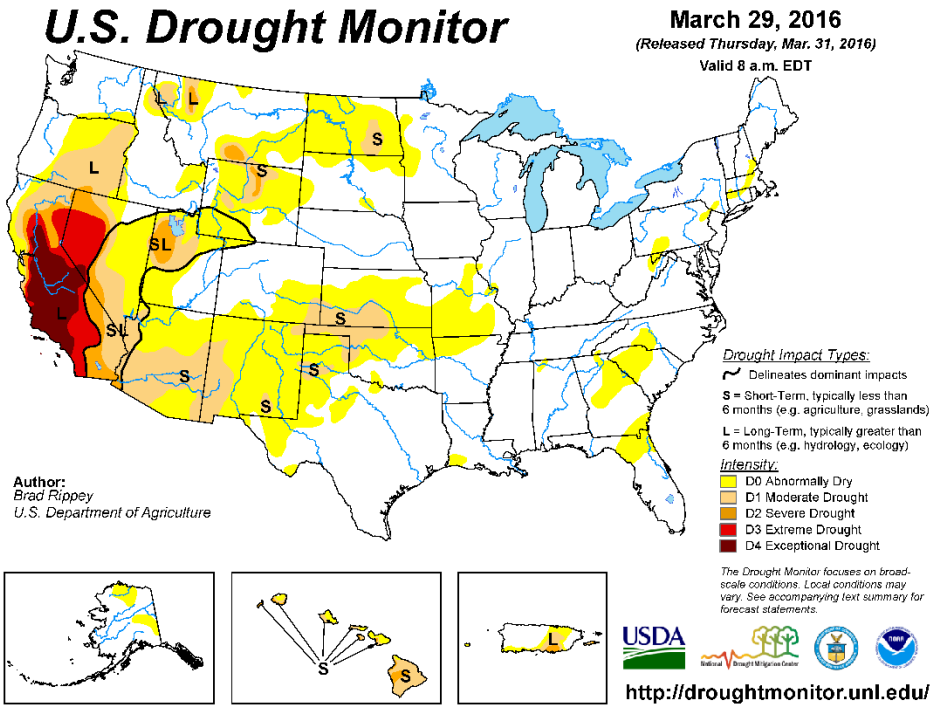


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for March 29, 2016.

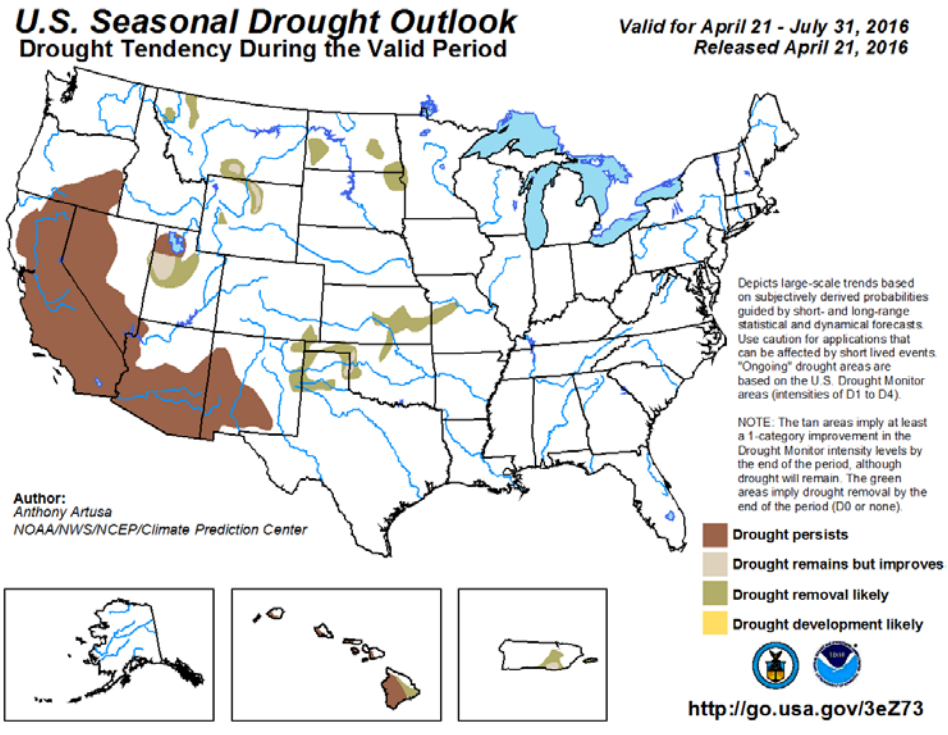


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

April precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). April precipitation was more than 150% of normal stretching northward from central Kansas through North Dakota, extending into eastern Colorado, most of Wyoming and eastern Montana, as well as western Iowa and northwestern Missouri, as a result of a series of storms beginning in mid-April. Precipitation was below normal in southwestern Montana, northwestern Wyoming, the Black Hills region of South Dakota extending into northeastern Wyoming, and most of Missouri.

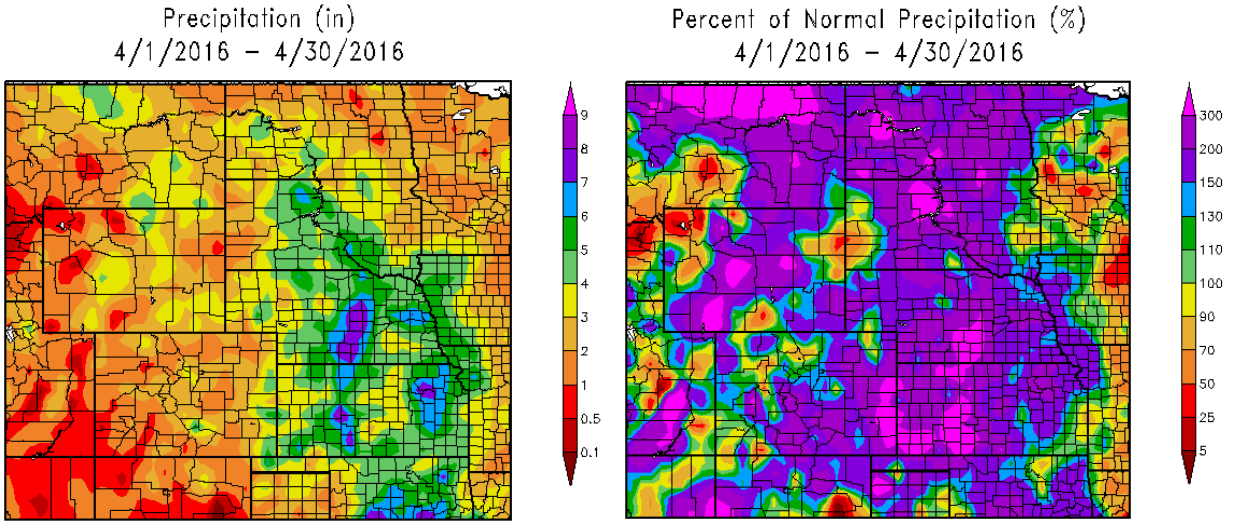


Figure 4. April 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 1 contains notable April precipitation and snowfall accumulations in these areas. Riverton, WY, Miles City, MT and Hill City, KS were locations that set month-of-April precipitation records. A large portion central Kansas, Nebraska and south-central South Dakota saw monthly precipitation values greater than 5 inches, as can be seen in **Table 1**. Precipitation was also above normal at the other locations listed in **Table 1** with the exception of Billings, MT. Snowfall totals were relatively heavy in portions of Colorado and Wyoming; however, little snowfall occurred in Montana.

Table 1. April 2016 snowfall and precipitation totals.

City, State	Snowfall inches	Precipitation inches	Precipitation Departure inches
Denver, CO	15.6	2.56	0.85
Riverton, WY	12.7	3.31*	2.01
Lander, WY	4.3	4.61	2.74
Worland, WY	m	1.34	0.48
Sheridan, WY	m	3.36	1.76
Casper, WY	14.5	3.63	2.34
Cheyenne, WY	19.4	3.06	1.28
Great Falls, MT	7.2	2.83	1.41

Havre, MT	T	3.55	2.71
Miles City, MT	m	4.36*	2.99
Billings, MT	1.8	1.28	-0.38
Glasgow, MT	3.2	2.61	1.76
Hill City, KS	m	6.72*	4.60
Goodland, KS	2.3	3.99	2.40
Topeka, KS	tr	6.92	3.39
Manhattan, KS	m	7.92	5.12
Kansas City, KS	0	7.15	3.45
St. Joseph, MO	m	6.43	2.64
Chadron, NE	m	3.66	1.68
Scottsbluff, NE	3.2	4.13	2.30
McCook, NE	m	6.10	3.79
Grand Island, NE	0	5.05	2.52
Kearney, NE	m	5.18	2.95
Hastings, NE	0	5.69	3.13
North Platte, NE	2.5	5.36	3.09
Valentine, NE	1.5	4.62	2.40
Omaha, NE	tr	5.40	2.44
Lincoln, NE	0	4.37	1.66
Norfolk, NE	tr	5.21	2.56
Sioux City, IA	0	5.81	2.86
Sioux Falls, SD	tr	4.62	1.61
Huron, SD	tr	4.14	1.83
Rapid City Arpt, SD	4.2	1.85	0.05
Faith, SD	m	4.02	2.39
Winner, SD	m	5.37	2.88
Aberdeen, SD	tr	3.66	1.81
Watertown, SD	tr	2.26	0.24
Pierre, SD	tr	3.92	2.11
Mobridge, SD	tr	4.62	3.05
Bismarck, ND	0.2	4.15	2.89
Williston, ND	0.0	1.95	0.95

* Indicates Record for the Month

February-March-April 2016 precipitation accumulations are shown in **Figure 5**. The precipitation pattern since January 1 is similar to the April pattern, with the most notable above-normal accumulations in Wyoming, eastern Montana, western North Dakota, central South Dakota, eastern Colorado, the western two-thirds of Nebraska and western Kansas. The remainder of the Basin was drier than normal from February through April.

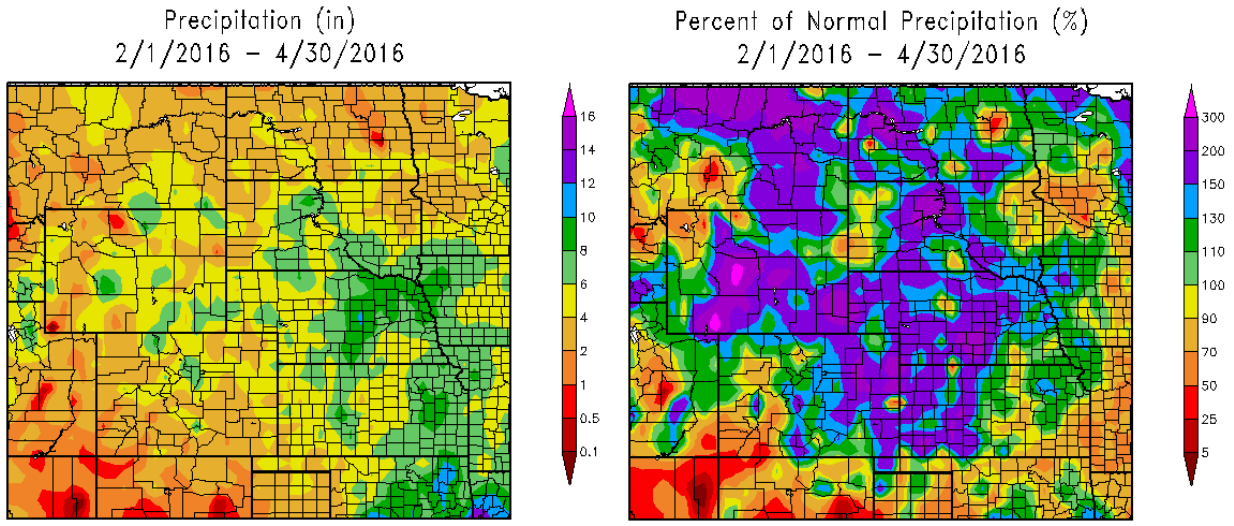


Figure 5. February-March-April 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

April temperature departures from normal are shown in **Figure 6** in degrees Fahrenheit (deg F). February-March-April 2016 temperature departures are also shown in **Figure 6**. Temperatures during March have ranged from near normal to slightly above normal through most of North Dakota into central South Dakota southwestward into portions of eastern Colorado to more than 5 deg F above normal in western Montana. Temperatures over the past three months have been 2-6 deg F above normal throughout nearly the entire basin, with only portions of eastern Colorado being near normal.

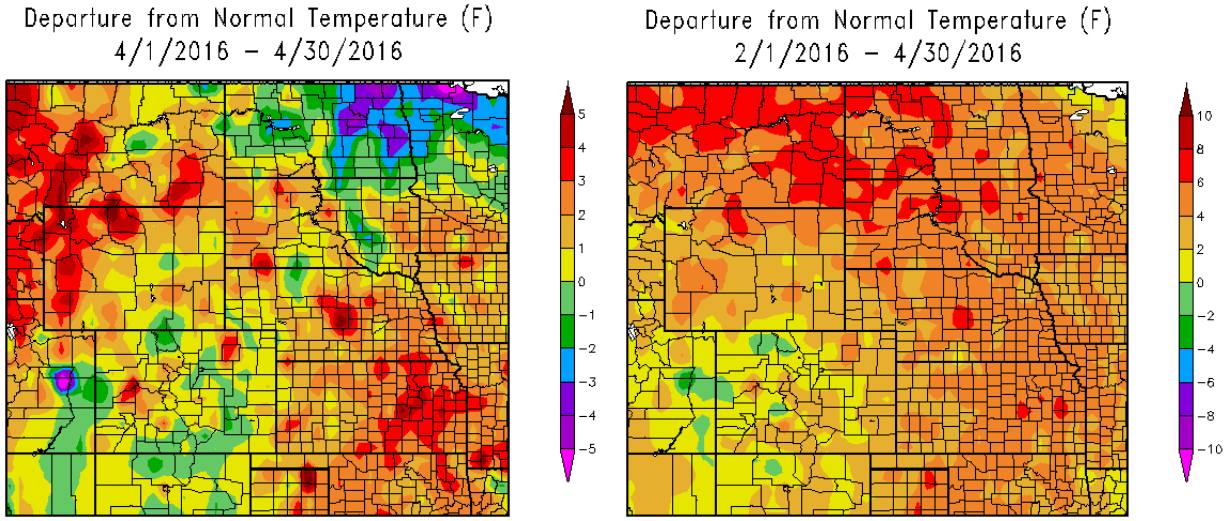


Figure 6. April 2016 and February-March-April 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 April 27, 2016. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above-normal soil moisture anomalies in eastern Montana, western North Dakota, much of Wyoming and South Dakota, nearly all of Nebraska, western Iowa, northwestern Missouri and most of Kansas. Below-normal soil moisture anomalies are present in small areas of south central Montana and north central Wyoming, eastern North Dakota, west central South Dakota and northeast Wyoming and eastern Kansas and Missouri.

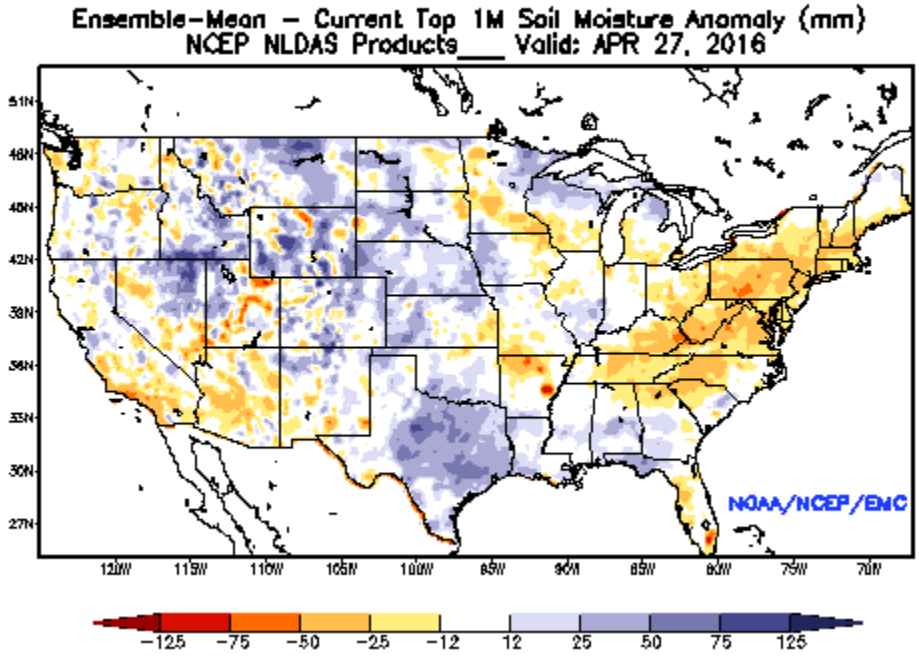


Figure 7. Top 1-Meter Soil Moisture Anomaly on April 27, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 8**. These conditions are based on the ranking of the May 2, 2016 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions are generally "Normal" (25^{th}-75^{th} percentile) above Garrison Dam and range from "Normal" (25^{th}-75^{th} percentile) to "Above Normal" (76^{th} – 90^{th} percentile) across

the rest of the Basin. Streamflow conditions are "Much Above Normal" (>90th percentile) to "High" (Daily High) across south-central South Dakota, much of eastern Nebraska and western Iowa and northwestern Missouri.

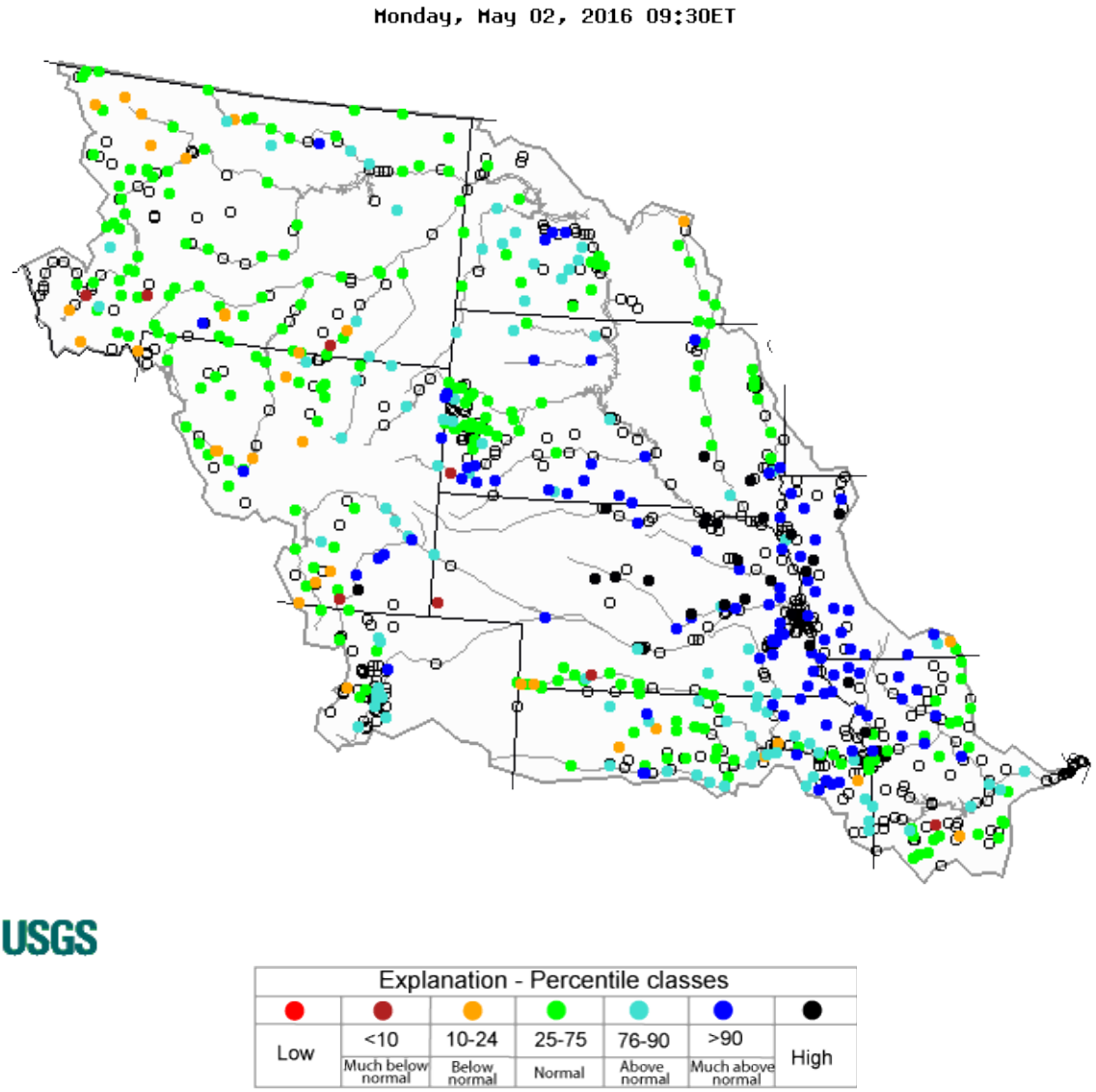


Figure 8. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of May 2, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Plains Snowpack

Based on the National Operational Hydrologic Remote Sensing Center (NOHRSC) assessment (**Figure 9**) as of May 2, 2016, there is little 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 and has little impact on total runoff.

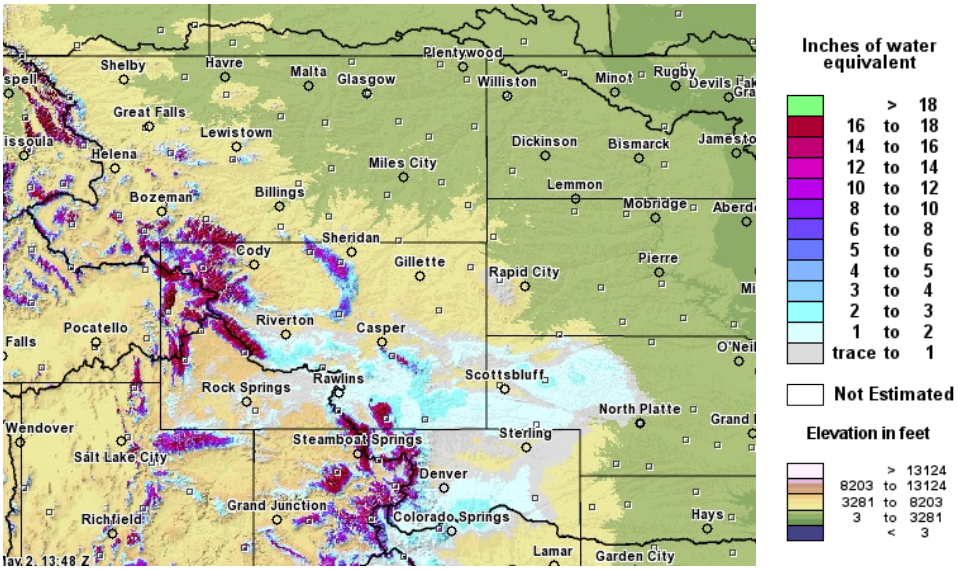


Figure 9. May 2, 2016 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

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 10 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 decreased over the past month, although the decreases have not been consistent spatially. On April 1 mountain SWE was 15.0 inches (95% of average) in the reach above Fort Peck and 12.2 inches (89% of average) from Fort Peck to Garrison. As of May 1, mountain SWE was 11.0 inches (75% of average) above Fort Peck and 11.6 inches (87% of average) from Fort Peck to Garrison. The Fort Peck reach peaked at 15.0 inches of SWE on April 1, while Fort Peck to Garrison peaked at 12.2 inches of SWE, or 93% and 86% of average annual peak SWE, respectively. Both reaches lost about 15% of their peak SWE during the first half of April due to warmer than normal temperatures and low precipitation, but Fort Peck lost another 15% of SWE during the second half of April, while the

Garrison reach gained nearly 11% during the same time due to differences in the distribution of precipitation. On average, about 92% of the peak SWE accumulation remains by May 1, as mountain snowpack normally peaks around April 15.

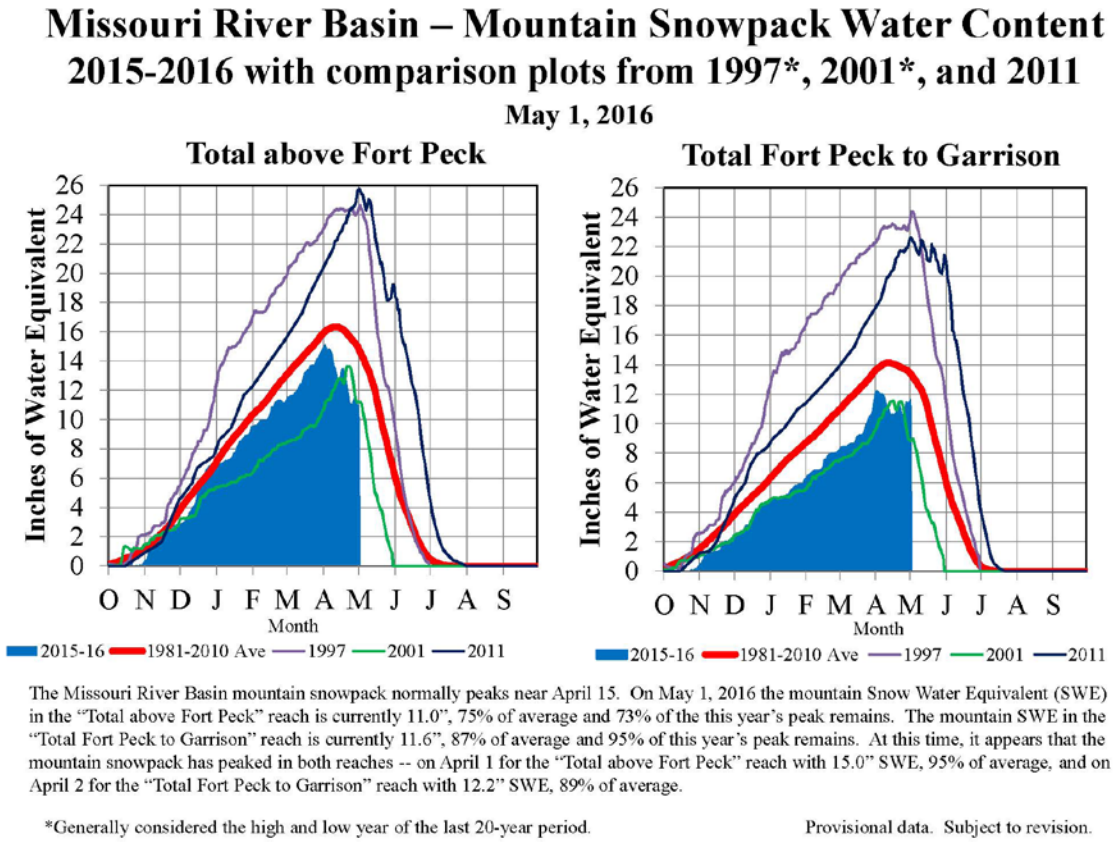


Figure 10. Mountain snowpack water content on May 1, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly update[1] on May 2, 2016, ***"El Niño is present and is weakening. A transition to ENSO-neutral is likely during late Northern Hemisphere spring or early summer 2016, with an increasing chance for La Niña during the second half of the year."***

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

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

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

The NOAA Climate Prediction Center climate outlook for April 2016 (**Figure 11)** indicates that above-normal temperatures will occur over much of the upper Basin in May. Probabilities for above-normal temperatures range from 33% chance temperatures will be above normal across central South Dakota and southern Montana to greater than 50% chances in northern Montana and northern North Dakota. Below-normal temperatures are indicated across southern Wyoming, western Nebraska and Kansas and all of Colorado. With regard to precipitation, there are increased chances (33% to greater than 40%) that below-normal precipitation will occur in North Dakota and eastern South Dakota, equal chances from Montana southeastward into southern Missouri, and above-normal chances (33% to greater than 40%) in Wyoming, Colorado and western Nebraska and Kansas.

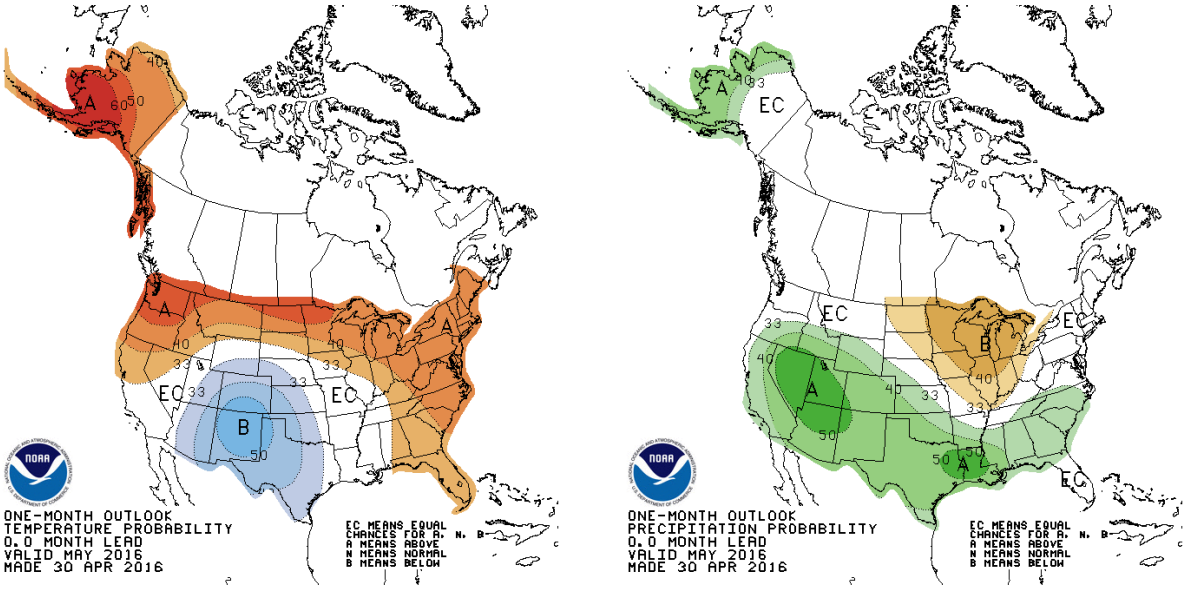


Figure 11. CPC May 2016 temperature and precipitation outlooks.

The May-June-July 2016 temperature outlook (**Figure 12**) indicates there are equal chances of above- or below-normal temperatures in southwestern Wyoming, far western Missouri and nearly all of Nebraska, Kansas and Colorado, with increased chances (33% to greater than 50%) for above-normal temperatures for the rest of the Basin. With regard to precipitation, the May-June-July outlook indicates there are equal chances over most of the upper Basin and most of Iowa, Nebraska and Missouri, and increased chances (33% to greater than 40%) for above-normal precipitation in much of Wyoming, Colorado and Kansas and western Nebraska. The August-September-October 2016 CPC temperature outlook (**Figure 13**) 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 increased chances for below-normal precipitation across Colorado, Kansas, southern Wyoming, Nebraska, southern Iowa and

northern Missouri, with equal chances for above- and below-normal precipitation in the rest of the Basin.

During the November-December 2016 – January 2017 period (**Figure 14**) CPC outlooks indicate increased chances (33% to greater than 40%) for above-normal temperatures in southern Wyoming, Colorado, Kansas, and southwestern Nebraska. There are increased chances for below-normal temperatures in Montana, North Dakota and extreme northern South Dakota, with equal chances for above-normal, normal and below-normal temperatures in the rest of the Basin. With regard to precipitation, the November-December-January outlook indicates there are increased chances (33% to greater than 40%) for above-normal precipitation in nearly all of Montana, and equal chances elsewhere in the Basin. The increased chances for below-normal temperatures and above-normal precipitation in Montana during November-December-January are a reflection of the possible impact that a La Niña ENSO pattern could have on the upper Basin climate.

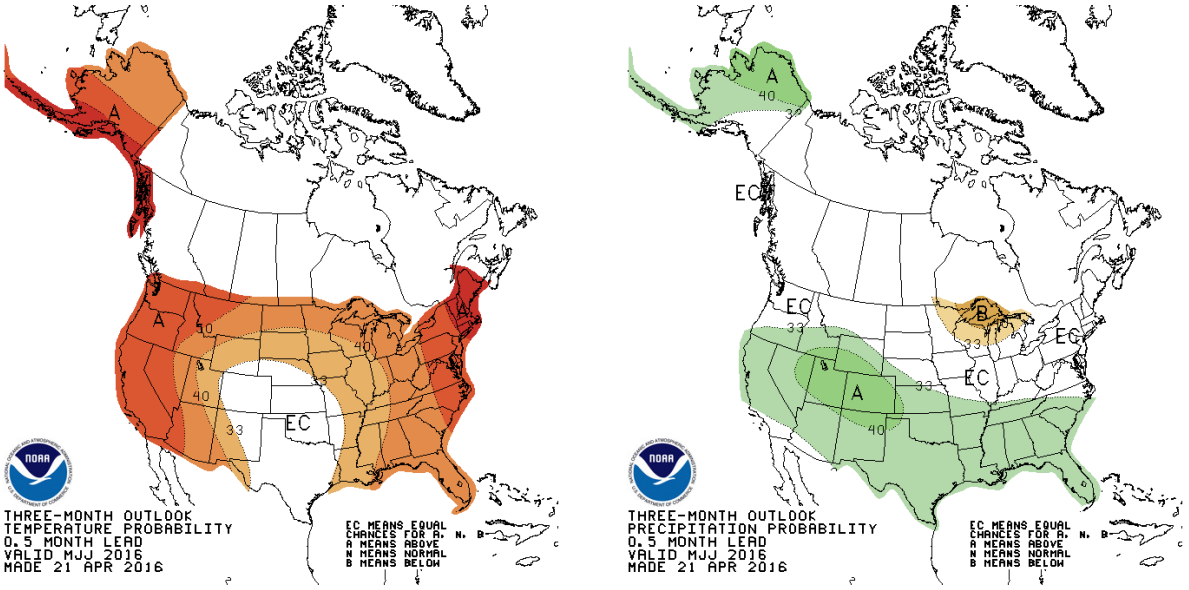


Figure 12. CPC May-June-July 2016 temperature and precipitation outlooks.

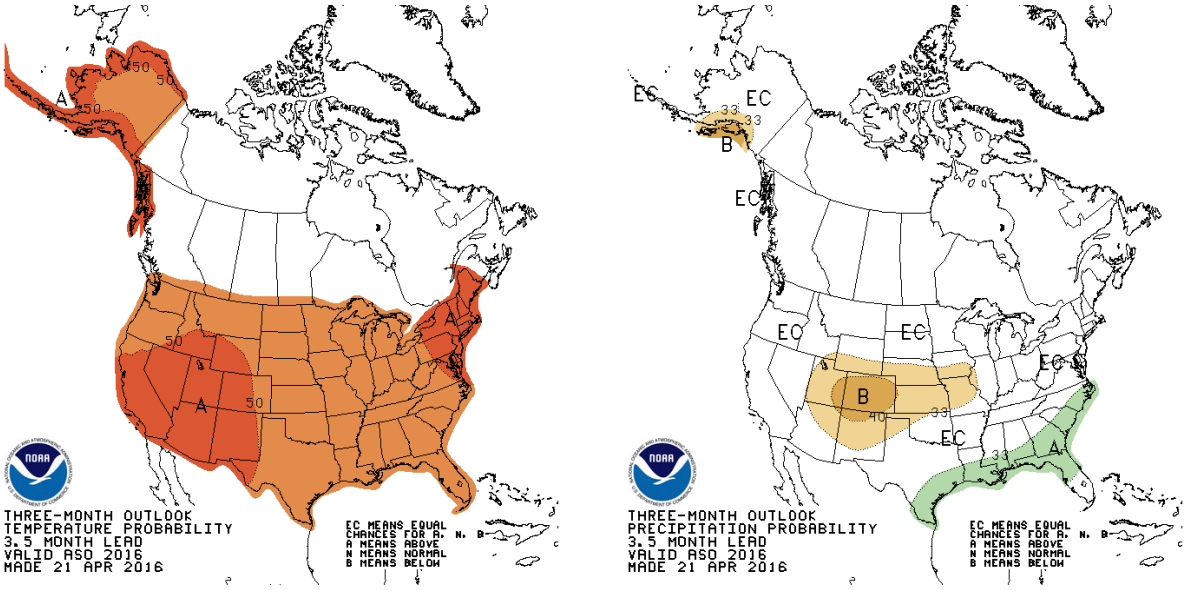


Figure 13. CPC August-September-October 2016 temperature and precipitation outlooks.

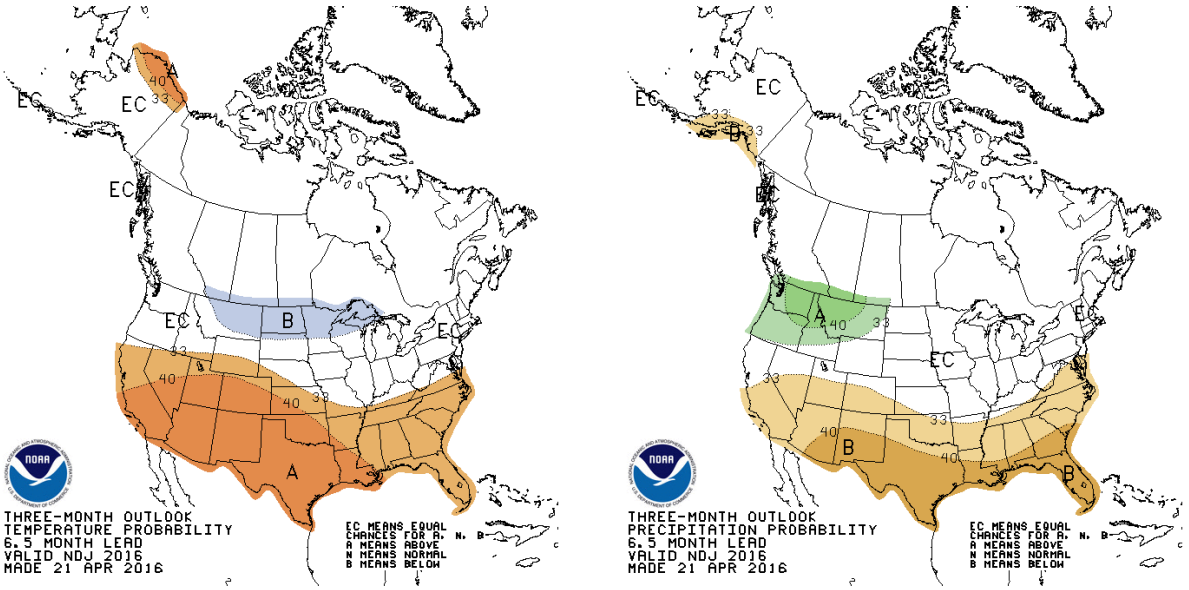


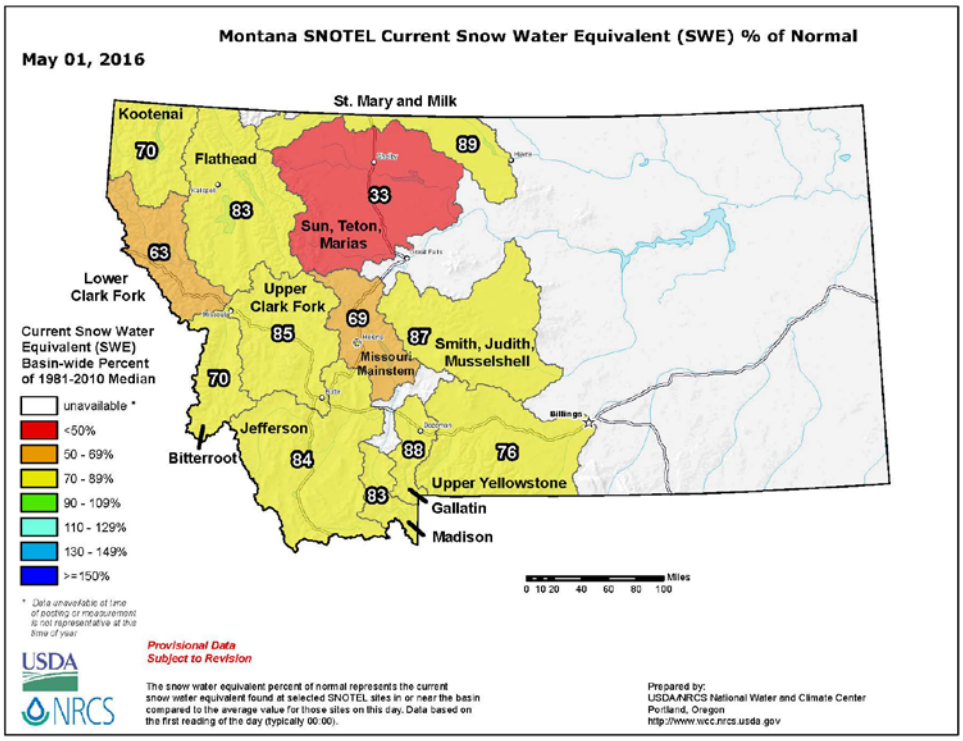
Figure 14. CPC November-December 2016-January 2017 temperature and precipitation outlooks.

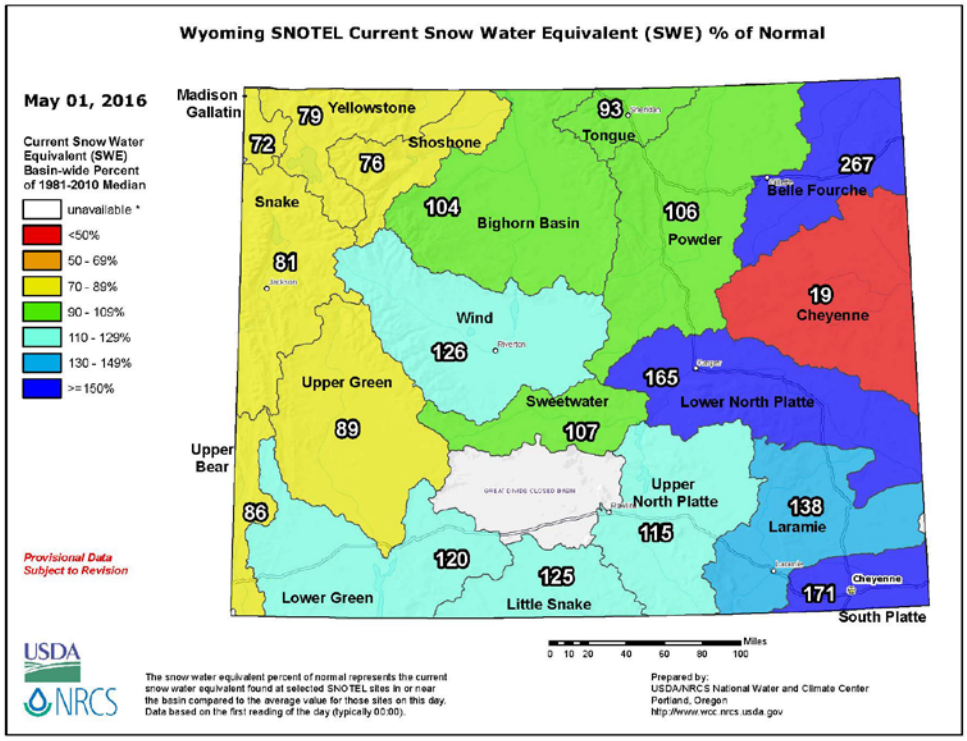
April 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **22.5 MAF**, **89% 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 **19.7 MAF (85% of average)**. Recent gains in the Fort Peck to Garrison mountain snowpack and wet weather over the plains has increased the May-June-

July runoff forecast compared to the April 1 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: May 04, 2016 06:50:46 PM
   - Based on May 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	MAY-JUL	69	80	83	75	63	55	86
	MAY-SEP	83	82	99	90	76	67	101
St. Mary R at Int'l Boundary (2)	MAY-JUL	315	79	400	350	280	230	400
	MAY-SEP	375	80	470	415	335	280	470
Lima Reservoir Inflow (2)	MAY-JUL	34	60	53	42	26	15.1	57
	MAY-SEP	37	58	59	46	28	14.7	64
Clark Canyon Reservoir Inflow (2)	MAY-JUL	35	55	94	59	11.3	-24	64
	MAY-SEP	47	57	110	73	21	-16.4	83
Jefferson R nr Three Forks (2)	MAY-JUL	480	83	770	595	360	188	575
	MAY-SEP	520	82	850	655	385	190	635
Hebgen Reservoir Inflow (2)	MAY-JUL	225	74	275	245	205	173	305
	MAY-SEP	305	75	365	330	280	245	405
Ennis Reservoir Inflow (2)	MAY-JUL	410	77	520	455	365	300	530
	MAY-SEP	540	79	670	595	485	410	680
Missouri R at Toston (2)	MAY-JUL	1240	84	1700	1420	1050	775	1480
	MAY-SEP	1460	83	2030	1690	1230	885	1760
Smith R bl Eagle Ck (2)	MAY-JUL	74	83	120	93	55	28	89
	MAY-SEP	85	86	141	108	62	29	99
Gibson Reservoir Inflow (2)	MAY-JUL	177	50	240	205	151	113	355
	MAY-SEP	210	53	280	235	179	137	395
Marias R nr Shelby (2)	MAY-JUL	110	39	255	168	52	15.0	285
	MAY-SEP	116	39	275	181	51	20	300

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	51	89	58	54	48	44	57
	MAY-SEP	65	90	76	69	61	54	72
Wind R ab Bull Lake Ck (2)	MAY-JUL	445	103	540	485	405	350	430
	MAY-SEP	475	102	585	520	430	365	465
Bull Lake Ck nr Lenore (2)	MAY-JUL	156	116	185	168	144	127	135
	MAY-SEP	190	114	225	205	175	153	166
Boysen Reservoir Inflow (2)	MAY-JUL	715	128	960	815	615	470	560
	MAY-SEP	775	126	1060	890	660	490	615
Greybull R nr Meeteetse	MAY-JUL	150	121	172	159	141	128	124
	MAY-SEP	205	121	250	225	186	158	170
Shell Ck nr Shell	MAY-JUL	41	79	55	47	35	27	52
	MAY-SEP	52	83	67	58	46	37	63
Bighorn R at Kane (2)	MAY-JUL	935	121	1250	1060	805	620	770
	MAY-SEP	1000	120	1350	1140	860	650	830
NF Shoshone R at Wapiti	MAY-JUL	390	91	470	425	360	310	430
	MAY-SEP	440	91	530	475	405	350	485
SF Shoshone R nr Valley	MAY-JUL	205	103	235	220	192	173	200
	MAY-SEP	240	102	275	255	225	205	235
Buffalo Bill Reservoir Inflow (2)	MAY-JUL	590	94	715	640	540	465	630
	MAY-SEP	660	94	800	715	605	520	700
Bighorn R nr St. Xavier (2)	MAY-JUL	1390	110	1790	1550	1240	1000	1260
	MAY-SEP	1480	110	1920	1660	1300	1040	1340
Little Bighorn R nr Hardin	MAY-JUL	61	72	91	73	49	31	85
	MAY-SEP	72	74	104	85	59	40	97

Tongue R nr Dayton (2)	MAY-JUL	70	88	97	81	59	43	80
	MAY-SEP	82	89	111	93	70	53	92
Tongue River Reservoir Inflow (2)	MAY-JUL	150	86	240	186	114	60	175
	MAY-SEP	171	86	265	210	132	75	198
NF Powder R nr Hazelton	MAY-JUL	7.7	93	10.4	8.8	6.6	5.0	8.3
	MAY-SEP	8.4	93	11.3	9.6	7.2	5.5	9.0
Powder R at Moorhead	MAY-JUL	139	92	225	174	104	53	151
	MAY-SEP	157	92	245	193	121	67	170
Powder R nr Locate	MAY-JUL	153	93	260	197	109	44	164
	MAY-SEP	172	93	290	220	124	53	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	3.0	77	6.5	4.4	1.53	0.50	3.9
Pactola Reservoir Inflow (2)	MAY-JUL	11.3	65	30	18.9	3.7	1.00	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	MAY-JUL	235	126	315	270	200	154	187
	MAY-SEP	265	126	360	305	225	171	210
Encampment R nr Encampment	MAY-JUL	138	117	171	151	125	105	118
	MAY-SEP	148	117	183	162	134	113	127
Rock Ck nr Arlington	MAY-JUL	54	113	65	59	49	43	48
	MAY-SEP	57	114	69	62	52	45	50
Seminoe Reservoir Inflow (2)	MAY-JUL	745	121	1040	865	625	450	615
	MAY-SEP	815	122	1140	945	685	490	670
Sweetwater R nr Alcova	MAY-JUL	51	111	74	60	42	28	46
	MAY-SEP	56	112	81	66	46	31	50
La Prele Ck ab La Prele Reservoir	MAY-JUL	22	148	31	26	18.4	13.0	14.9
	MAY-SEP	23	155	32	27	19.4	14.1	14.8
North Platte R bl Glendo Res (2)	MAY-JUL	860	128	1100	960	760	615	670
	MAY-SEP	895	128	1150	995	795	645	700
North Platte R bl Guernsey Res (2)	MAY-JUL	860	128	1160	980	740	565	670
	MAY-SEP	905	129	1210	1030	780	600	700
Laramie R nr Woods	MAY-JUL	140	130	174	154	126	106	108
	MAY-SEP	153	129	191	168	138	115	119
Little Laramie R nr Filmore	MAY-JUL	57	119	71	63	51	43	48
	MAY-SEP	61	117	77	67	55	45	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