Upper Missouri River Basin
June 2016 Calendar Year Runoff Forecast
June 8, 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.

May 2016 Runoff

May 2016 Missouri River Basin above Sioux City, IA (upper Basin) runoff was 4.5 MAF (136% of average). May runoff was 114% of average in the Fort Peck reach, 128% of average in the Garrison reach, 75% of average in the Oahe reach, 170% of average in the Fort Randall reach, 214% of average in the Gavins Point reach, and 244% of average in the Sioux City reach. Significant rainfall events resulted in runoff being above average in the Fort Randall, Gavins Point, and Sioux City reaches. Earlier-than-normal snowmelt in the Rocky Mountains and areas of above-average rainfall resulted in above-average runoff in the Fort Peck and Garrison reaches.

2016 Calendar Year Forecast Synopsis

The June 1 forecast for 2016 upper Basin runoff is **25.3 MAF (100% of average)**. Runoff for the basin above Gavins Point Dam is forecast to be **21.8 MAF (94% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 7 months, the range of expected inflow is quite large and ranges from the 30.4 MAF upper basic forecast to the 20.8 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 7 months are being forecasted for this June 1

forecast (5 months observed/7 months forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all 6 reaches for 7 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 May 31, 2016 (**Figure 1**), when compared to the drought monitor for April 26, 2016 (**Figure 2**), shows very limited change to drought conditions in the upper Basin. There has been some improvement to conditions in north central Wyoming and northwest Montana. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought is expected to ease in Montana and Wyoming; however, drought is expected to develop in northeast North Dakota.

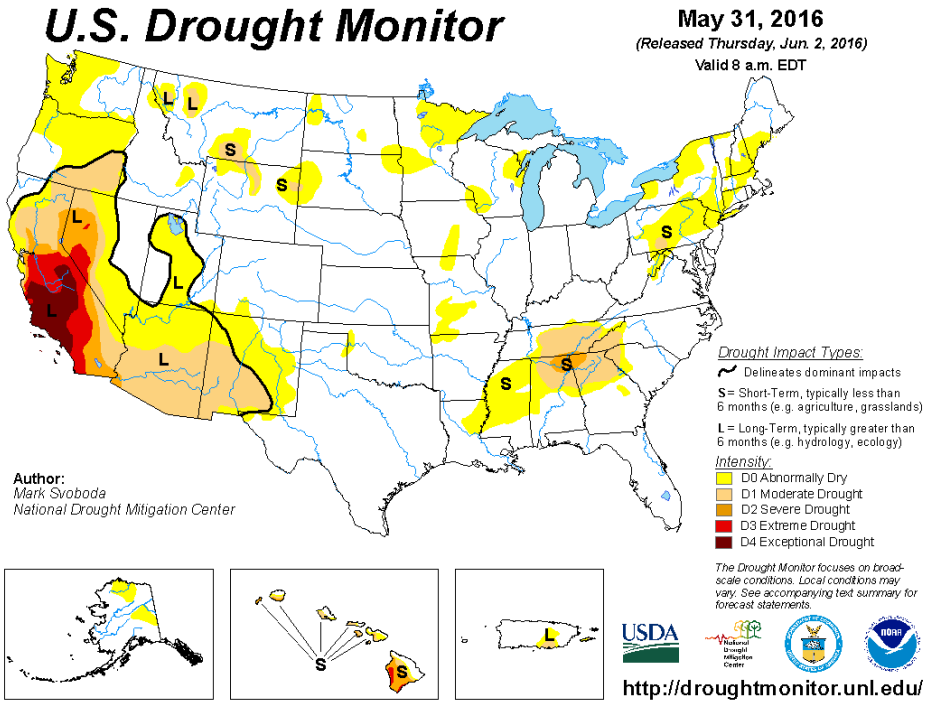


Figure 1 National Drought Mitigation Center U.S. Drought Monitor for May 31, 2016

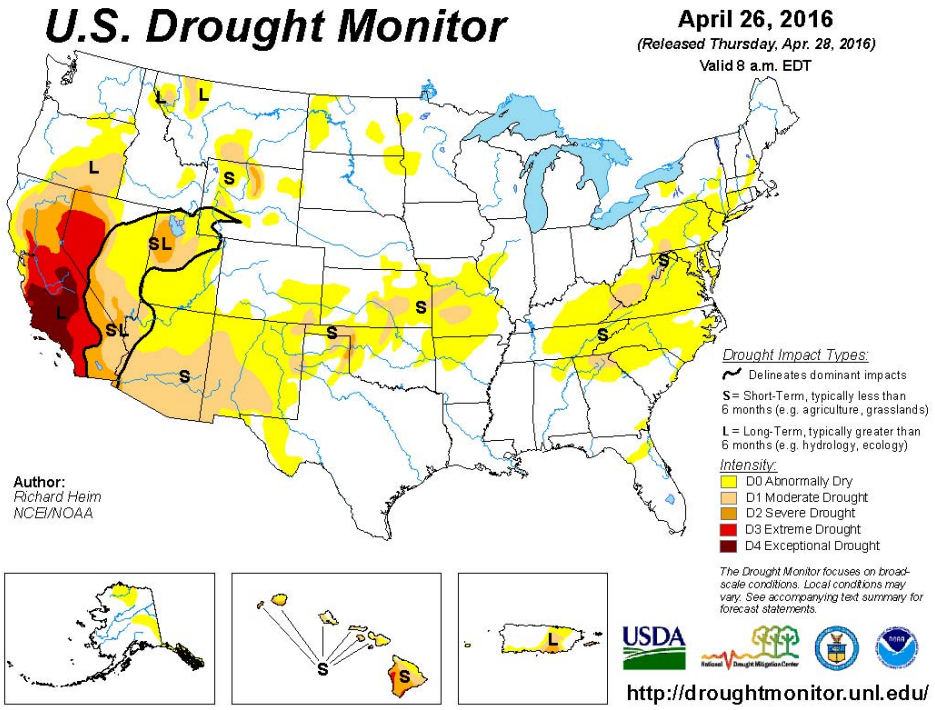


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for April 26, 2016.

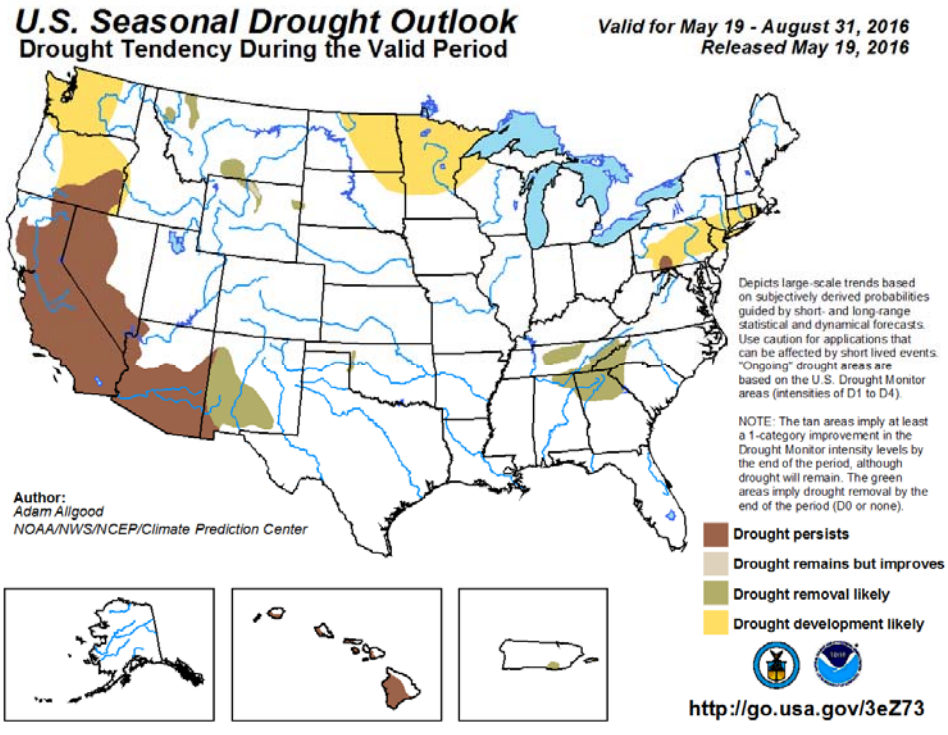


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

May precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). May precipitation was above average to more than 150% of average over a large portion of central and northern Montana, portions of central and southern Wyoming, the Gavins Point reach, and parts of the lower Basin extending from southeast South Dakota through Nebraska and Kansas into western Missouri. In contrast, May precipitation was less than 50% of average in southeast Montana, northeast Wyoming, western and central South Dakota, and southwest North Dakota.

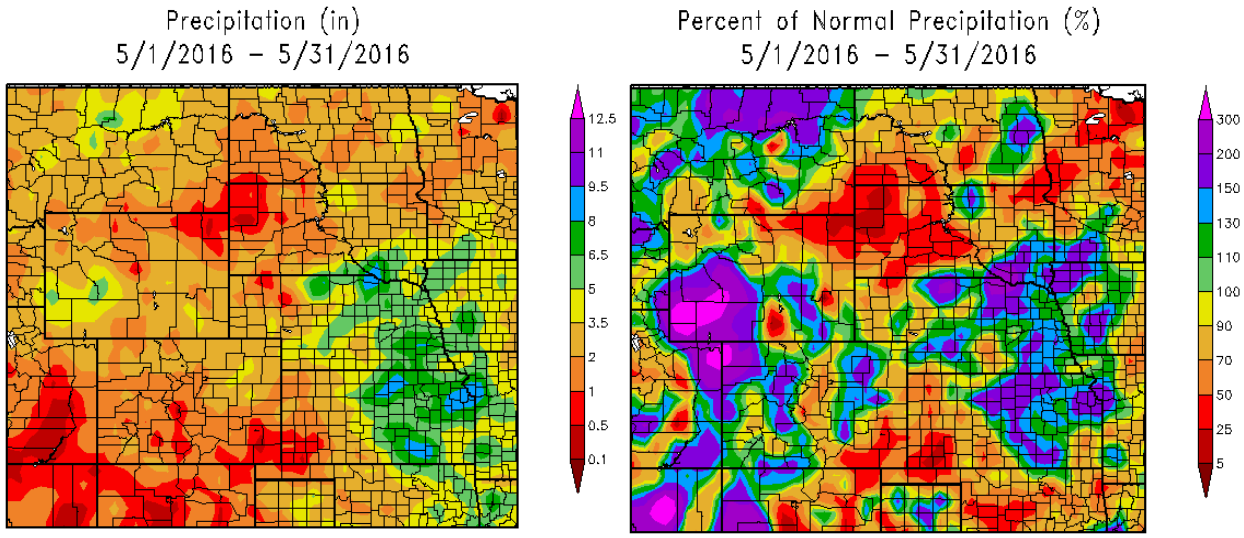


Figure 4. May 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 1 contains notable May precipitation and departures in many locations in the Missouri Basin. Precipitation departures were variable in Montana and Wyoming ranging from large above-average departures in Havre, MT and Lander, WY to large below-average departures in Sheridan, WY and Gillette, WY. Below-average precipitation that occurred in the Oahe Basin is highlighted by below-average departures across much of central and western South Dakota. In contrast to this area of below-average precipitation, above-average precipitation departures were observed in much of the lower Basin. Notable departures in the lower Basin include: 2.43 inches above average in Grand Island, NE; 3.91 inches above average in Topeka, KS; and, 4.27 inches above average at the Kansas City International Airport.

Table 1. May 2016 precipitation and precipitation departures.

City, State	Precipitation inches	Precipitation Departure inches
Bozeman, MT	2.56	0.06
Lewistown, MT	3.98	1.13
Livingston, MT	2.41	-0.25
Great Falls, MT	2.04	-0.38
Havre, MT	3.48	1.74

City, State	Precipitation inches	Precipitation Departure inches
Miles City, MT	2.43	0.25
Billings, MT	2.04	-0.14
Glasgow, MT	4.46	2.54
Wolf Point, MT	1.97	0.19
Lander, WY	5.03	2.83
Lake Yellowstone, WY	2.81	0.54
Sheridan, WY	1.06	-1.29
Gillette, WY	0.67	-1.78
Jamestown, ND	2.79	0.13
Bismarck, ND	1.96	-0.44
Williston, ND	1.81	-0.11
Huron, SD	2.73	-0.38
Rapid City Arpt, SD	0.84	-2.38
Aberdeen, SD	2.13	-0.98
Watertown, SD	2.10	-0.54
Pierre, SD	1.20	-1.95
Mobridge, SD	3.75	0.93
Sioux Falls, SD	3.11	-0.29
Sioux City, IA	5.02	1.28
Valentine, NE	7.09	3.96
North Platte, NE	3.90	0.62
Grand Island, NE	6.84	2.43
Norfolk, NE	6.68	2.75
Lincoln, NE	5.42	1.13
Omaha, NE	4.84	0.08
Manhattan, KS	5.88	1.40
Topeka, KS	8.82	3.91
Lawrence, KS	7.38	2.19
Kansas City Intl Arpt, KS	9.50	4.27
St. Joseph, MO	5.92	0.50

March-April-May 2016 precipitation accumulations and percent of normal (average) precipitation are shown in **Figure 5**. The precipitation pattern since March 1 shows above-average precipitation (right image) in north central and portions of central Montana, a majority of Wyoming, southern South Dakota, Nebraska, western Iowa, northeast Colorado and Kansas. A below-average precipitation pattern has been prevalent in southeast Montana, southwest North Dakota, northeast Wyoming and western South Dakota. Furthermore, the lower Basin in central and eastern Missouri has received below-average precipitation since March 1.

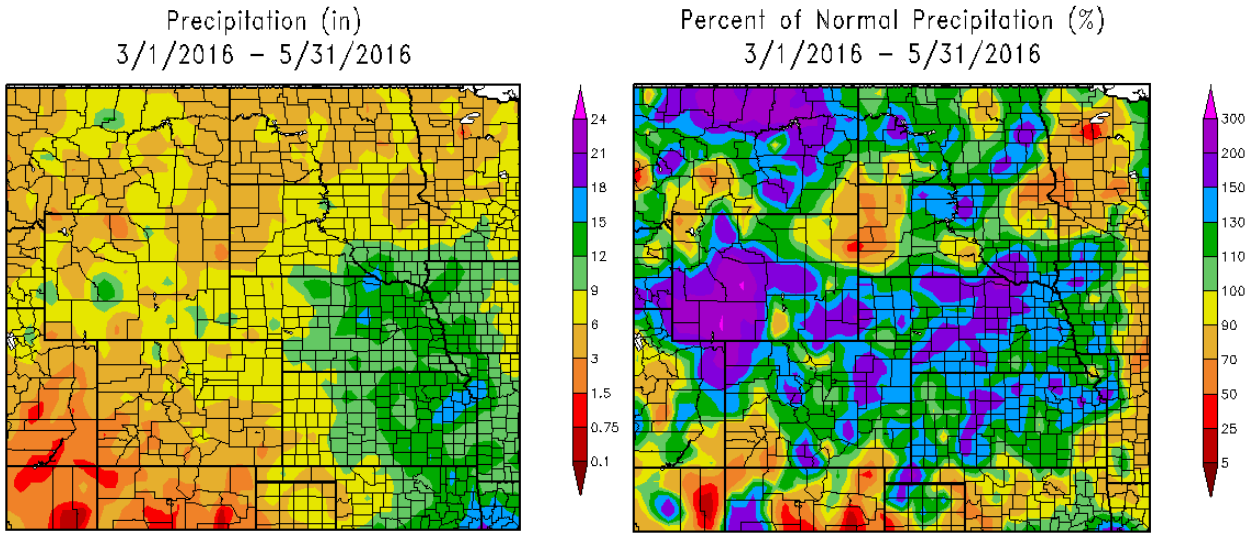


Figure 5. March-April-May 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

May temperature departures from normal are shown in the left image of **Figure 6** in degrees Fahrenheit (deg F). March-April-May 2016 temperature departures are also shown in the right image of **Figure 6**. Temperatures during May (left image) have been below normal across most of the Rocky Mountains in Montana and Wyoming, in the Central Plains of Nebraska, northeast Colorado, Kansas, Iowa and Missouri. The cooler temperatures are a reflection of moist May conditions and the frequent track of weather systems that have delivered the moisture. In contrast, temperatures were above normal in eastern Montana, North Dakota and much of South Dakota. During the March-April-May period, an overall warmer-than-normal temperature pattern has prevailed throughout the entire Missouri Basin. Warmer temperatures in March and April led to earlier-than-normal peak mountain snow accumulations and earlier-than-normal snowmelt in the Northern Rockies. Temperatures in the Central Rockies have been near to below normal, resulting in normal peak mountain snow accumulations and snowmelt in the Platte River basin.

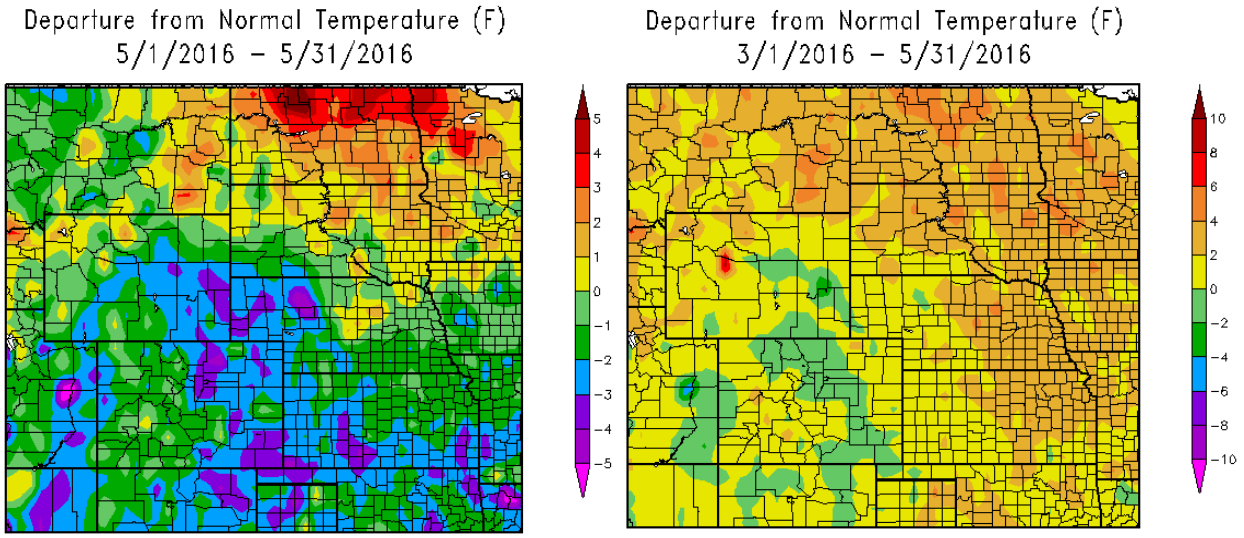


Figure 6. May 2016 and March-April-May 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 June 2, 2016. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above-normal soil moisture anomalies in northern and central Montana, western North Dakota, much of Wyoming, eastern South Dakota, Nebraska, western Iowa, eastern Colorado, Kansas, and northwest Missouri. Below-normal soil moisture anomalies are present in the several mountain ranges of Montana and northern Wyoming, portions of North Dakota, and western South Dakota.

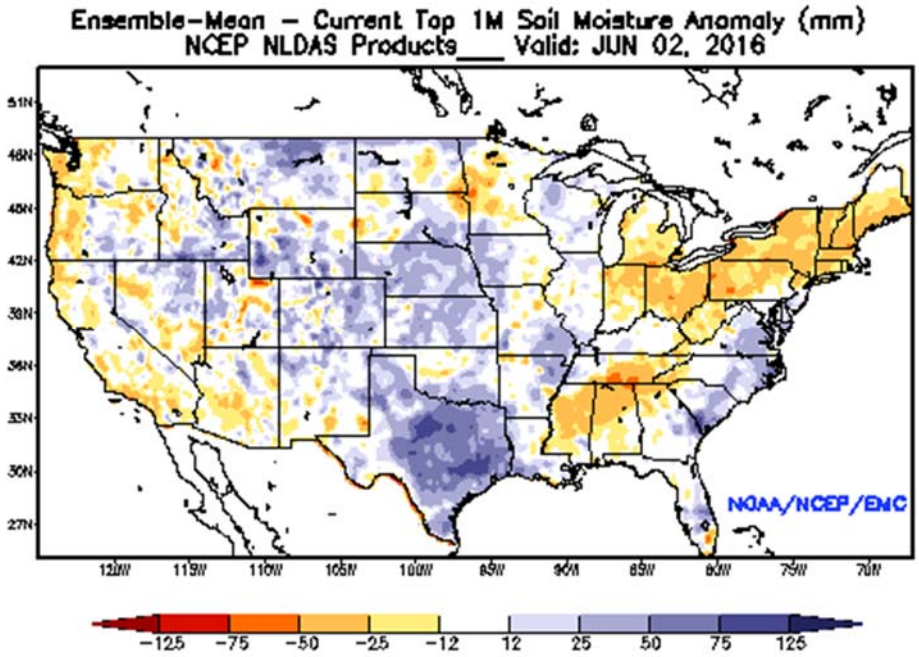


Figure 7. Top 1-Meter Soil Moisture Anomaly on June 2, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 8**. These conditions are based on the ranking of the June 1, 2016 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions are generally "Normal" (25th-75th percentile) in Montana and Wyoming, though there are a number of tributaries that have fallen into the "Below Normal" (10th to 24th percentile) class as a result of early low elevation mountain snowmelt and below-average precipitation. Streamflow has also been "Normal" to "Below Normal" in North Dakota, and from western to northeast South Dakota. Streamflow in the North Platte Basin in southeast Wyoming is "Above Normal" (76th – 90th percentile) to "Much Above Normal" (>90th percentile). The Missouri River and its tributaries from Sioux City to Kansas City range from "Above Normal" to "Much Above Normal" due to above-average precipitation in May.

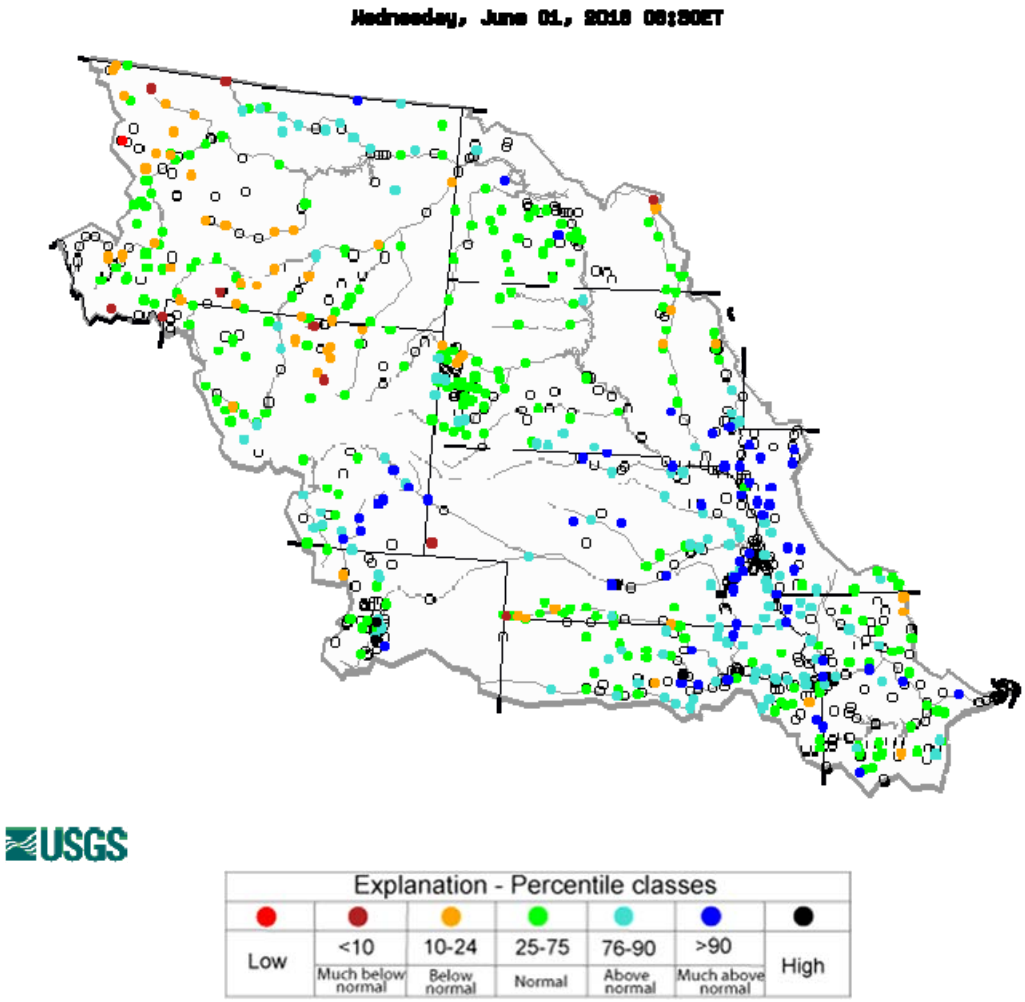


Figure 8. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of June 1, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Mountain Snowpack

Mountain snowpack is the primary factor used to predict June-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reaches. During the 3-month May-June-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 June-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 snow water equivalent (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). On average, mountain SWE normally peaks around April 15, and about 39% of the peak SWE accumulation remains by June 1.

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 on April 2, or 95% and 89% of average annual peak SWE, respectively. The mountain SWE has decreased rapidly over the past month as low to mid-level mountain snowpack melted due to warmer-than-normal temperatures in the Northern Rockies. On May 1, mountain SWE was 11.0 inches (75% of average) in the reach above Fort Peck and 11.6 inches (87% of average) from Fort Peck to Garrison. As of May 31, mountain SWE was 4.6 inches (74% of average) above Fort Peck and 4.5 inches (72% of average) from Fort Peck to Garrison. High elevation snowpack was occurring during the first week of June and is expected to be substantially complete by mid-June.

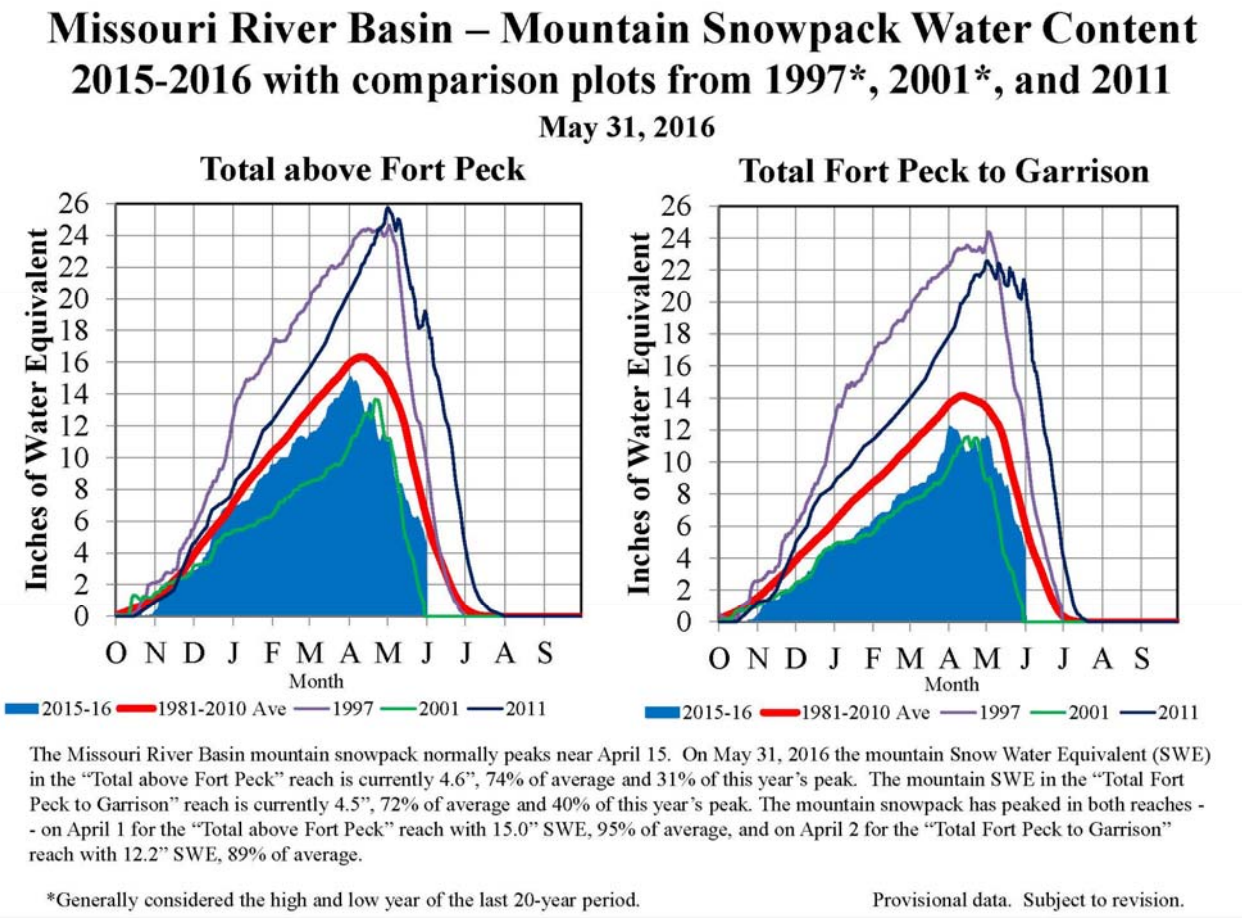


Figure ~~9~~10. Mountain snowpack water content on May 31, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly updated[1] on May 30, 2016, "***El Niño is weakening. La Niña is favored to develop during the Northern Hemisphere summer 2016, with about a 75% chance of La Niña during the fall and winter 2016-2017.***"

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 La Niña climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin. During La Niña winters, the probability for a colder-than-normal and slightly wetter-than-normal weather pattern in the Northern Rockies and Northern Plains is higher. The possible impacts of La Niña have been factored into the CPC climate outlooks described below.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for June 2016 (**Figure 11)** indicates there are increased probabilities for above-normal temperatures in Montana and Wyoming, equal chances in the center of the Missouri Basin, and slightly increased chances for below-normal temperatures in the lower Basin. With regard to precipitation, there are equal chances for above-normal, normal and below-normal precipitation in the Missouri Basin; however, the mid-term outlooks through mid-June indicate the Missouri Basin will be drier-than-normal.

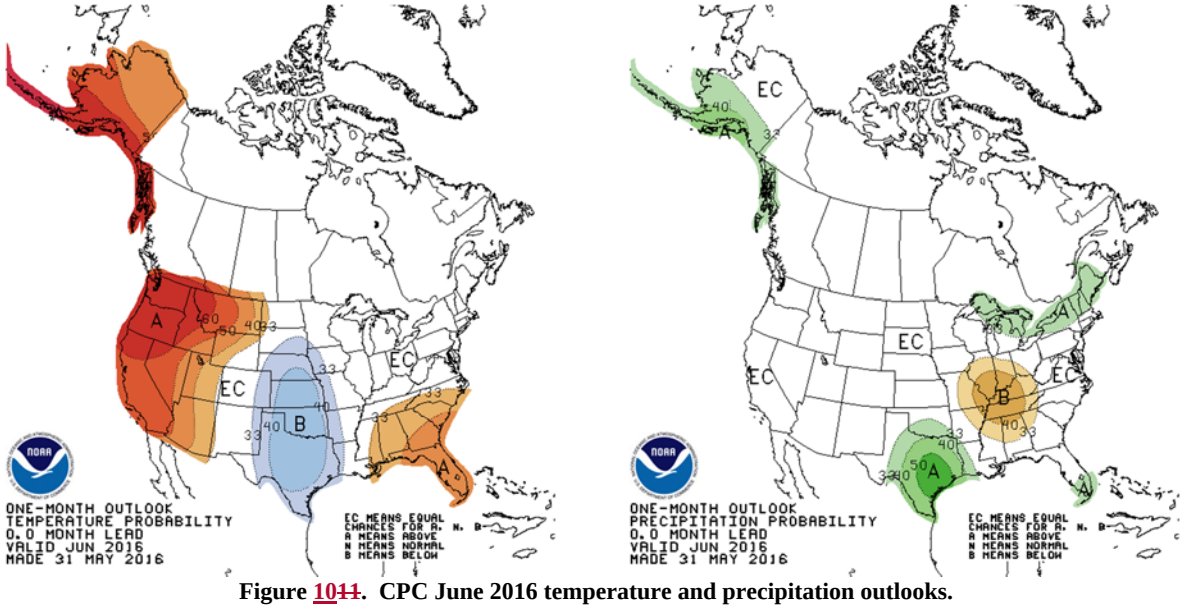


Figure 10~~11~~. CPC June 2016 temperature and precipitation outlooks.

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

The June-July-August 2016 temperature outlook (**Figure 12**) indicates there are equal chances of above- or below-normal temperatures in the center of the Missouri Basin, surrounded by increased chances for above-normal temperatures in the remainder of the Missouri Basin. The equal chances area is a reflection of moist soil conditions, which can reduce daytime temperatures, and the possibility of a continued storm track through the center of the Missouri Basin. With regard to precipitation, the June-July-August outlook indicates there are equal chances over Montana and North Dakota, but slightly increased chances for above-normal precipitation from southern Montana through Wyoming, South Dakota, Nebraska, Colorado, western Iowa, Kansas and western Missouri.

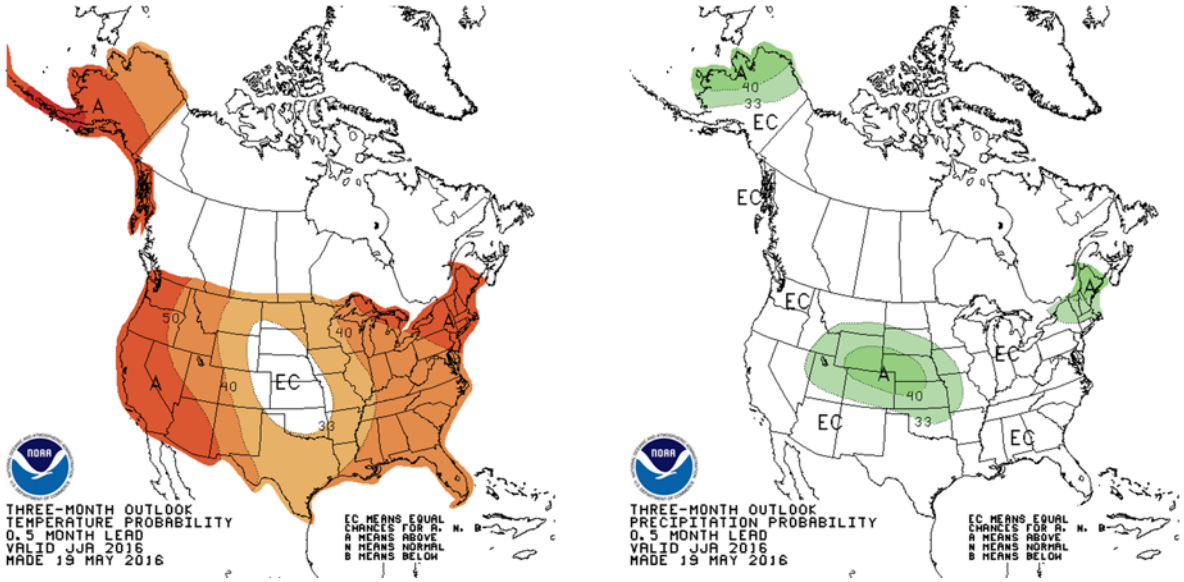


Figure 11~~12~~. CPC June-July-August 2016 temperature and precipitation outlooks.

The September-October-November 2016 CPC temperature outlook (**Figure 13**) indicates there are increased chances (40% to greater than 50%) for above-normal temperatures across the entire Missouri Basin. In terms of precipitation, there are equal chances for above-normal, normal and below-normal precipitation across Missouri Basin.

During the December 2016 – January-February 2017 period (**Figure 14**) CPC outlooks indicate increased chances (33% to greater than 40%) for below-normal temperatures in the Northern Rockies and Northern Plains based on the 75% chance that La Niña will develop in the fall and winter. Also, the CPC outlook indicates increased chances (33% to greater than 40%) that precipitation will be above normal in Montana. There are equal chances for precipitation in most other areas of the Missouri Basin through February 2017.

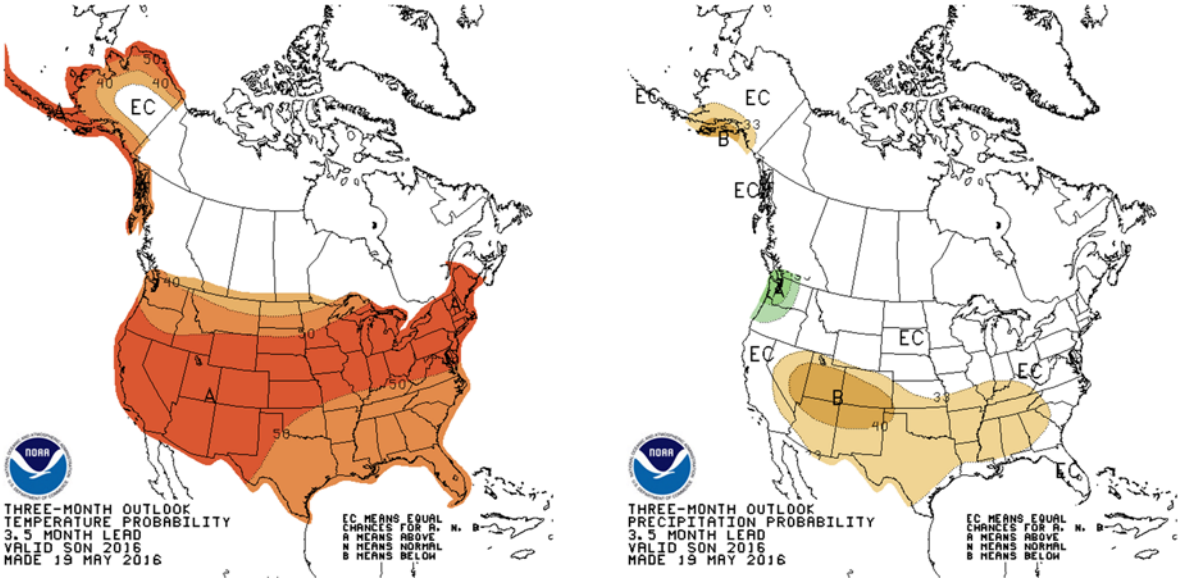


Figure 12~~13~~. CPC September-October-November 2016 temperature and precipitation outlooks.

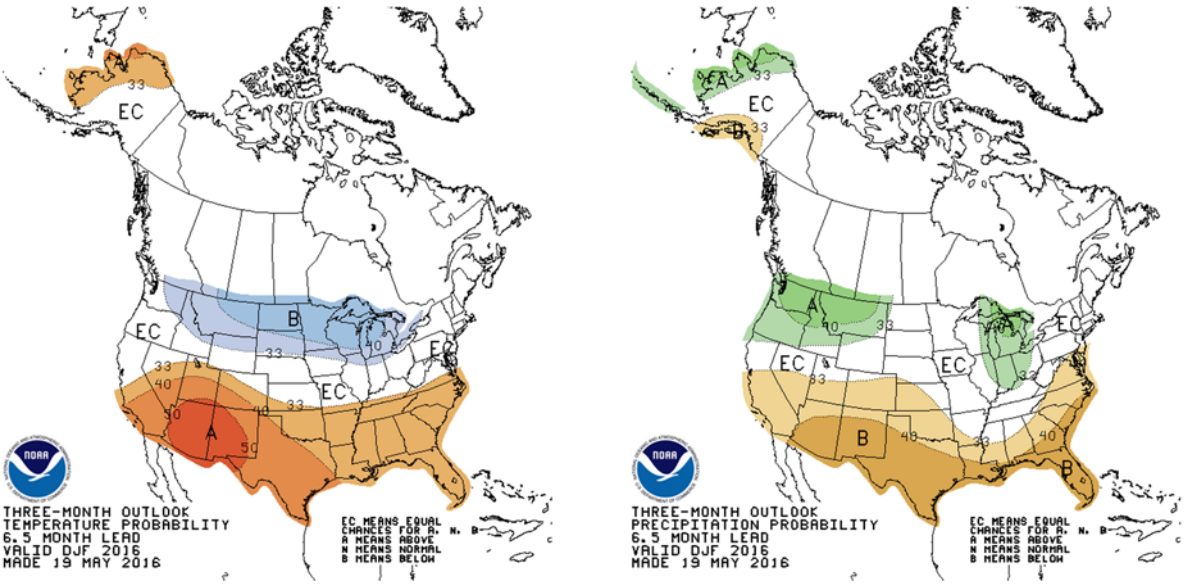
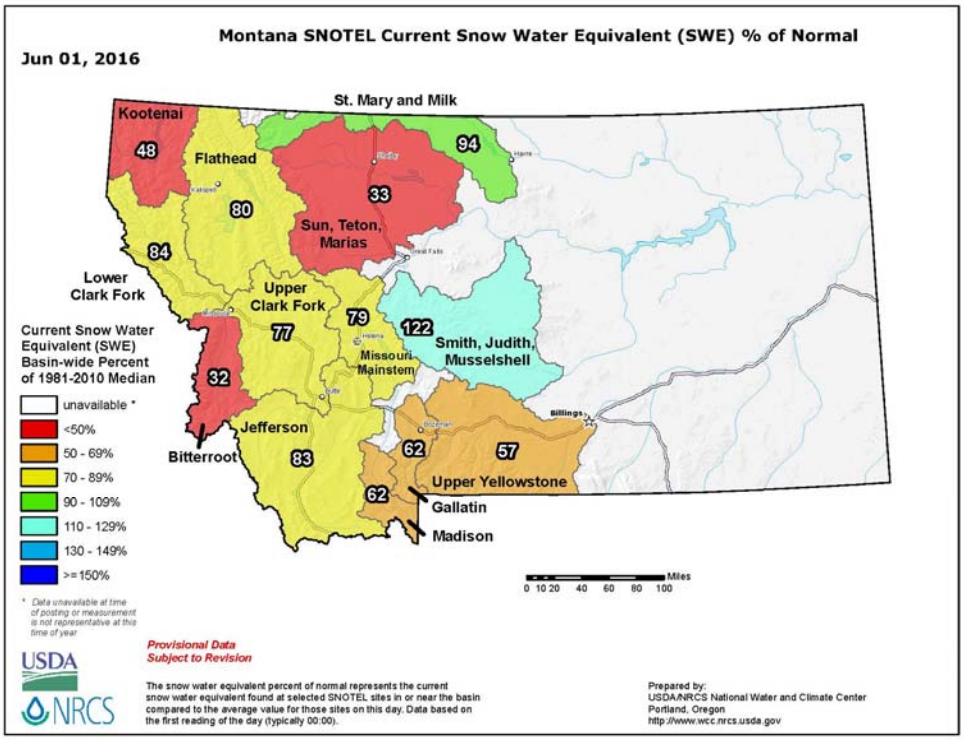


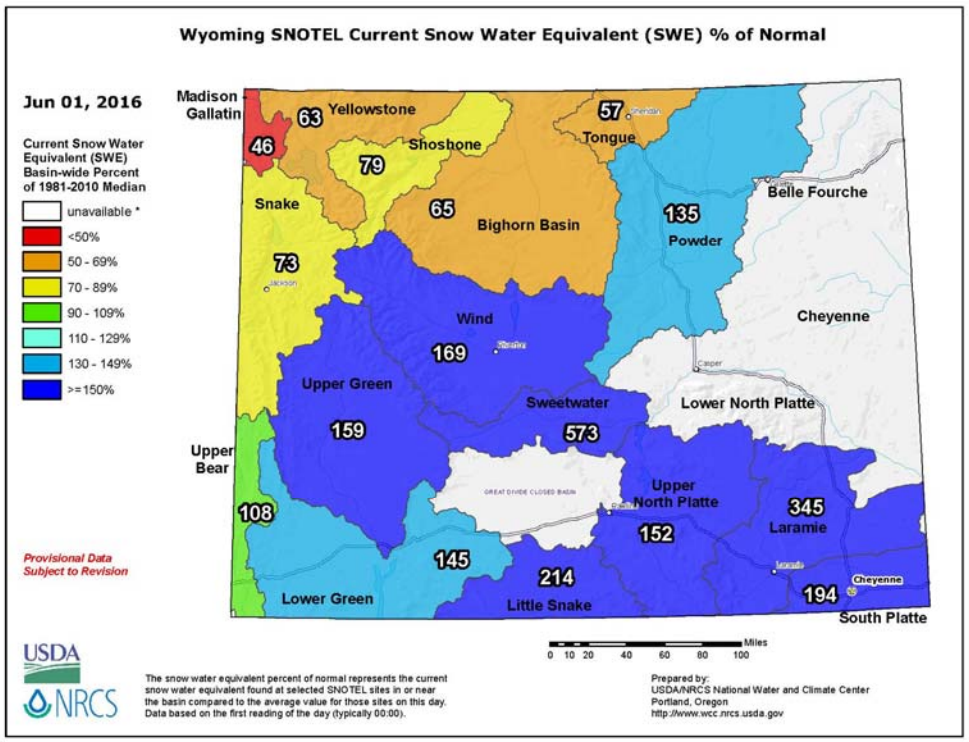
Figure 13~~14~~. CPC December 2016-January-February 2017 temperature and precipitation outlooks.

June 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **25.3 MAF**, **100% 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 **21.8 MAF (94% of average)**. May runoff was 136% of average. The above-normal runoff was due to mountain snowmelt and above-average observed precipitation in the upper Basin. We will continue to monitor Missouri Basin conditions and make forecast adjustments as conditions change.

Additional Figures





USDA NRCS National Water & Climate Center
 * - DATA CURRENT AS OF: June 06, 2016 01:28:36 PM
   - Based on June 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	JUN-JUL	47	84	60	52	42	34	56
	JUN-SEP	61	86	76	67	55	46	71
St. Mary R at Int'l Boundary (2)	JUN-JUL	220	80	290	245	191	149	275
	JUN-SEP	280	81	355	310	250	200	345
Lima Reservoir Inflow (2)	JUN-JUL	20	65	34	26	14.5	6.3	31
	JUN-SEP	25	64	43	32	17.9	7.4	39
Clark Canyon Reservoir Inflow (2)	JUN-JUL	21	60	65	39	3.1	-23	35
	JUN-SEP	34	62	84	54	13.6	-16.4	55
Jefferson R nr Three Forks (2)	JUN-JUL	290	82	480	365	210	96	355
	JUN-SEP	345	83	575	440	250	109	415
Hebgen Reservoir Inflow (2)	JUN-JUL	126	71	169	143	109	83	178
	JUN-SEP	210	75	260	230	189	158	280
Ennis Reservoir Inflow (2)	JUN-JUL	260	79	325	285	235	193	330
	JUN-SEP	395	81	480	430	360	310	485
Missouri R at Toston (2)	JUN-JUL	725	77	1090	875	575	360	940
	JUN-SEP	970	80	1480	1180	765	465	1220
Smith R bl Eagle Ck (2)	JUN-JUL	55	102	89	69	41	21	54
	JUN-SEP	67	103	112	85	48	21	65
Gibson Reservoir Inflow (2)	JUN-JUL	115	55	169	137	93	61	210
	JUN-SEP	150	60	210	173	127	92	250
Marias R nr Shelby (2)	JUN-JUL	65	45	175	109	21	-15.0	143
	JUN-SEP	76	48	200	127	25	-15.0	158

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)	JUN-JUL	40	85	48	43	37	32	47
	JUN-SEP	53	84	64	57	49	42	63
Wind R ab Bull Lake Ck (2)	JUN-JUL	360	109	455	400	320	265	330
	JUN-SEP	395	108	505	440	350	285	365
Bull Lake Ck nr Lenore (2)	JUN-JUL	137	127	161	147	128	114	108
	JUN-SEP	172	124	205	185	159	140	139
Boysen Reservoir Inflow (2)	JUN-JUL	635	149	820	710	560	450	425
	JUN-SEP	705	145	935	800	610	475	485
Greybull R nr Meeteetse	JUN-JUL	113	118	138	123	103	88	96
	JUN-SEP	164	115	197	177	151	131	142
Shell Ck nr Shell	JUN-JUL	21	60	31	25	17.1	11.5	35
	JUN-SEP	30	65	41	35	25	18.6	46
Bighorn R at Kane (2)	JUN-JUL	765	134	1010	860	670	525	570
	JUN-SEP	860	137	1160	980	740	560	630
NF Shoshone R at Wapiti	JUN-JUL	275	90	330	295	250	215	305
	JUN-SEP	325	90	395	355	295	250	360
SF Shoshone R nr Valley	JUN-JUL	155	99	181	165	145	129	157
	JUN-SEP	187	99	220	200	173	153	189
Buffalo Bill Reservoir Inflow (2)	JUN-JUL	440	95	545	480	400	335	465
	JUN-SEP	510	95	640	565	460	380	535
Bighorn R nr St. Xavier (2)	JUN-JUL	1090	118	1400	1220	970	785	920
	JUN-SEP	1220	121	1620	1380	1050	815	1010
Little Bighorn R nr Hardin	JUN-JUL	32	60	61	44	20	3.3	53
	JUN-SEP	42	64	76	56	28	8.0	66

Tongue R nr Dayton (2)	JUN-JUL	30	61	46	36	24	14.0	49
	JUN-SEP	41	66	60	49	33	22	62
Tongue River Reservoir Inflow (2)	JUN-JUL	63	57	107	81	45	18.0	110
	JUN-SEP	81	60	137	104	59	25	134
NF Powder R nr Hazelton	JUN-JUL	2.7	60	4.9	3.6	1.84	0.56	4.5
	JUN-SEP	3.4	65	5.8	4.3	2.4	0.97	5.2
Powder R at Moorhead	JUN-JUL	67	73	121	89	45	12.2	92
	JUN-SEP	87	79	153	114	60	21	110
Powder R nr Locate	JUN-JUL	74	73	146	103	45	2.3	101
	JUN-SEP	95	78	186	132	58	4.3	122

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