

RECLAMATION

Managing Water in the West

Flaming Gorge Technical Working Group

May 7, 2018 Hydrology Summary

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For the purposes of discussions related to implementing the ROD in 2018, an evaluation has been made of the current hydrologic conditions in the Upper Green River (*i.e.* above Flaming Gorge Dam) and Yampa River Basins. The evaluation centered on the historical unregulated inflow statistics for Flaming Gorge Dam during the period from 1963 through 2017. The May 2018 April-July forecast is 1,000,000 acre-feet (1,000 kaf) for Flaming Gorge, which falls in the average (below median) hydrologic classification. Information regarding Yampa River hydrology indicates that the hydrologic classification will likely be moderately dry (>70% and <90% exceedance) for spring 2018.

The official Colorado River Basin Forecast Center (CBRFC) combined May Final Forecast of the Yampa River at Maybell and Little Snake at Lily is 841,000 acre-feet. This forecast would fall into the moderately dry hydrologic classification of the ROD.

Snow water equivalent (SWE) as of May 7, 2018, for the Upper Green River and Yampa/White River Basins are 99 and 74 percent of median, respectively. Flaming Gorge SWE is similar to 1987 and 1968, while Deerlodge SWE is similar to 2001 and 1955. The Tower snotel site, used as a reference point for Yampa snowpack and runoff, currently has 44.6 inches of SWE (87 percent of median). On May 7, 2001 the Tower SNOTEL measured a SWE of 38.2 inches during a runoff season where the Yampa yielded 790 kaf (62% of average, Maybell + Lily).

The difference between the Tower SNOTEL figures and Yampa River observed spring volume differs significantly and needs to be considered when comparing any values this early in the runoff season.

Basin Hydrology

Green River Basin Hydrology

The May final Forecast of the April through July unregulated inflow (current forecast) for Flaming Gorge Reservoir is 1,000,000 acre-feet (AF) (102% of 30-year average). This forecast falls at 55 percent exceedance based on the historic unregulated inflow record (1963-2017).

Figure 1 illustrates the Upper Green River SWE as of May 7, 2018 and compares it against the nearest April-July water years 1987 and 2015.

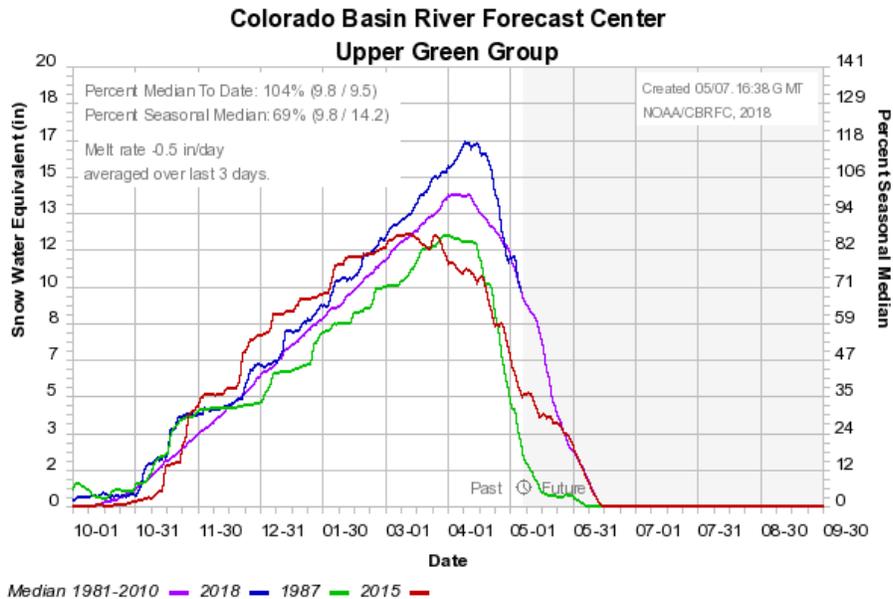


Figure 1 - Upper Green River Basin SNOTEL Tracking. 1981-2010 percent of median compared against 2018 YTD Snow Water Equivalent (SWE), and analog years 2015 and 1987.

Figure 2 shows the spatial extent of significant areas of modeled snow accumulation for the Upper Green River Basin and how this is incorporated into the water supply forecasts.

Snow Conditions - May 07 2018

(Modeled, Major Contributing Areas)

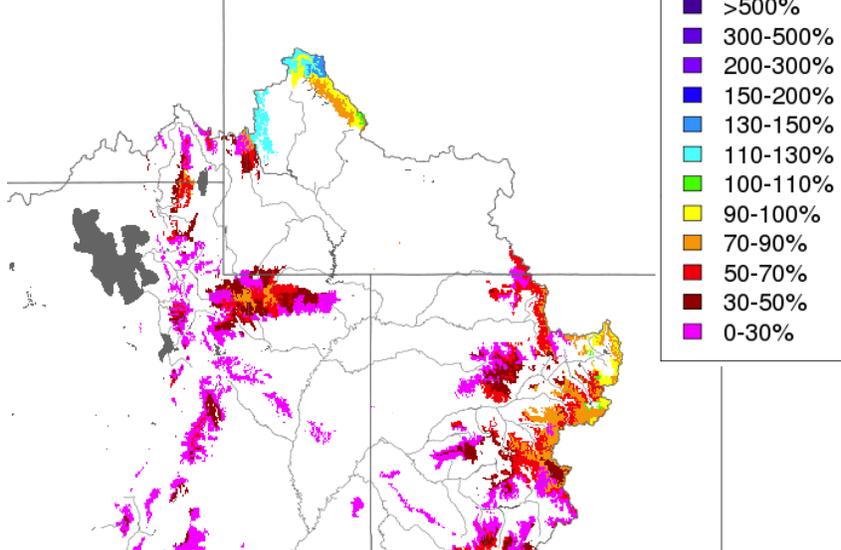


Figure 2 - Upper Green River and Yampa River Basins modeled SWE significant areas as of May 7, 2018.

The CBRFC Water Supply Forecast for the Upper Green River Basin is provided in Figure 3. This figure indicates that the forecast for Flaming Gorge Reservoir has remained fairly stable across the snowpack season with a slight increase in April. The May forecast of 1,000 kaf (Apr-Jul) is equal to what was forecasted in the April final Forecast.

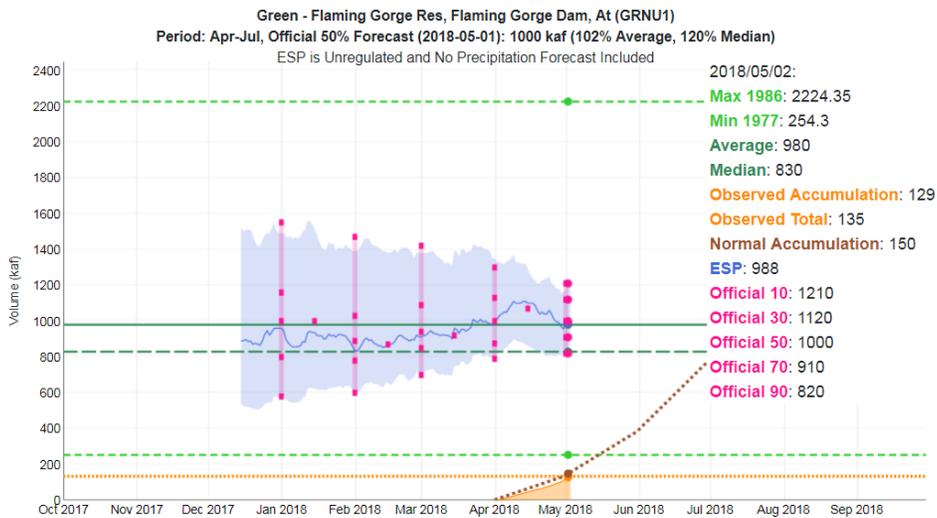


Figure 3 - Upper Green River Basin Water Supply Forecast as of May 7, 2018.

The analogous years unregulated inflow volumes (based off of the May final Forecast) are 1987 with total inflow into Flaming Gorge of 982 kaf (100 percent of 30-year average) and 2015 with total inflow into Flaming Gorge of 1,035 kaf (106 percent of 30-year average). SWE analog years will differ from unregulated inflow volumes because of the inclusion of spring precipitation events separate from snowmelt in total runoff volumes.

Figure 4 illustrates the May final Forecast (Apr-Jul) for Flaming Gorge (1,000 kaf) in relation to the historic unregulated inflow volumes (1963 through 2017). Figure 5 illustrates Flaming Gorge Reservoir April final forecast probability (percent exceedance). For both figures the most, minimum and maximum forecast values are taken from the May final Forecast.

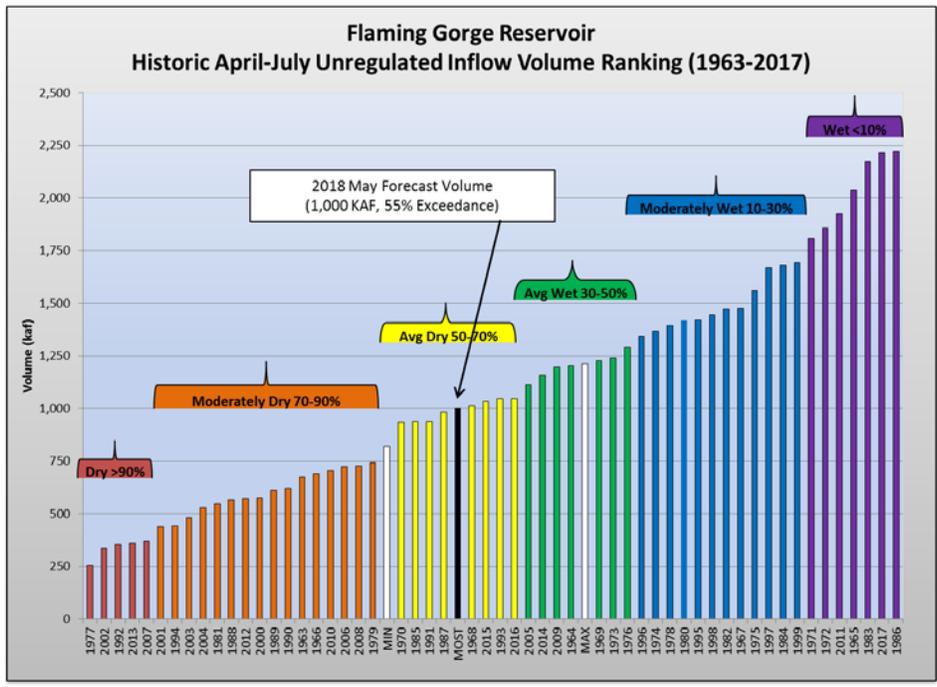


Figure 4 - Flaming Gorge Reservoir – May final Forecast and ranked historic April-July unregulated inflow volume for years 1963-2017.

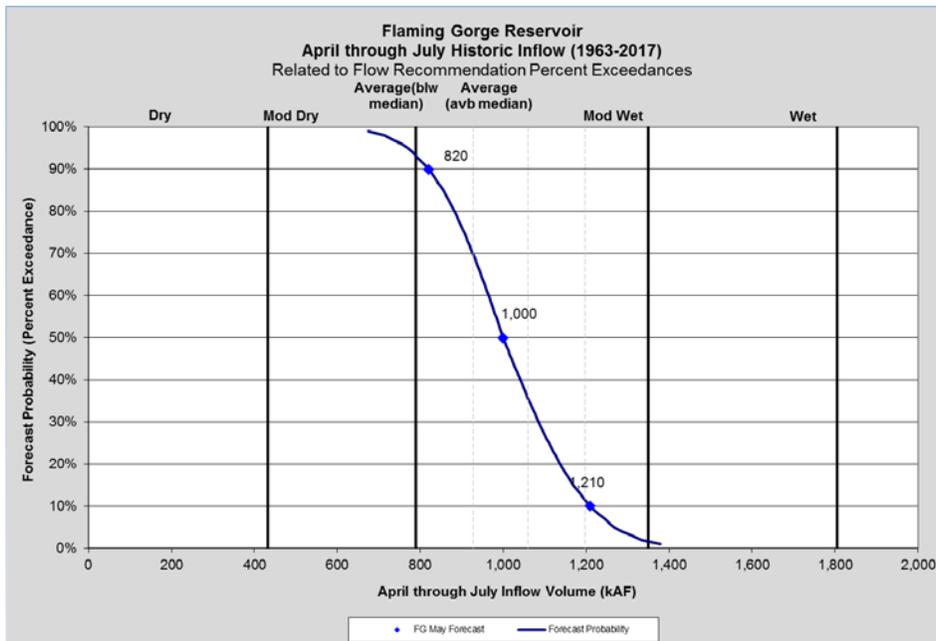


Figure 5 - Flaming Gorge Reservoir – May final Forecast probability (percent exceedance) and historic April-July unregulated inflow volume for years 1963-2017.

Yampa River Basin Hydrology

The combined current forecast for the Little Snake at Lily plus Yampa River at Maybell based on the May final Forecast is 841 kaf (66.4% of 30-year average). This forecast falls at approximately 81% exceedance based on a ranking of the historic record (1922-2017).

Figure 6 illustrates the Yampa River at Deerlodge Park SWE as of May 7, 2018 and compares it against the nearest April-July water year unregulated inflow volume in 2001. While the year 1955 is also viewed as an analogous year to 2018 in terms of forecasted April-July runoff, snowpack data for 1955 is unavailable. The next highest year for which snowpack data is available is 1991, which is included in Figure 6.

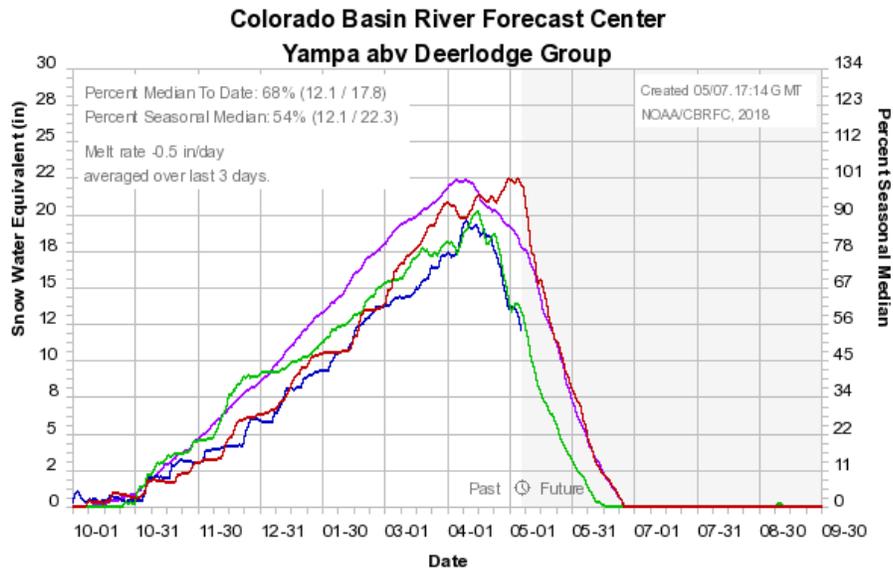


Figure 6 - Yampa River above Deerlodge SNOTEL Group. 1981-2010 percent of average SWE compared against 2018 YTD, and analog years 2001 and 1991.

Similar to what was presented in the Green River Basin Hydrology section, Figure 2 also demonstrates the extent of modeled SWE in the Yampa River Basin. Figure 7 indicates that the forecast for the Yampa River at Deerlodge Park has increased over the month of April with the final forecast, released on May 1, 2018 forecasting an April-July runoff of 815 kaf.¹

¹ The Yampa River at Deerlodge forecast volume differs from the Yampa River – Maybell Plus Lily volume. The historic gage record to calculate the Maybell plus Lily forecast volume is significantly longer than the Deerlodge dataset. The forecast volumes will be close, but the actual volume may differ due to routing in the CBRFC forecast model.

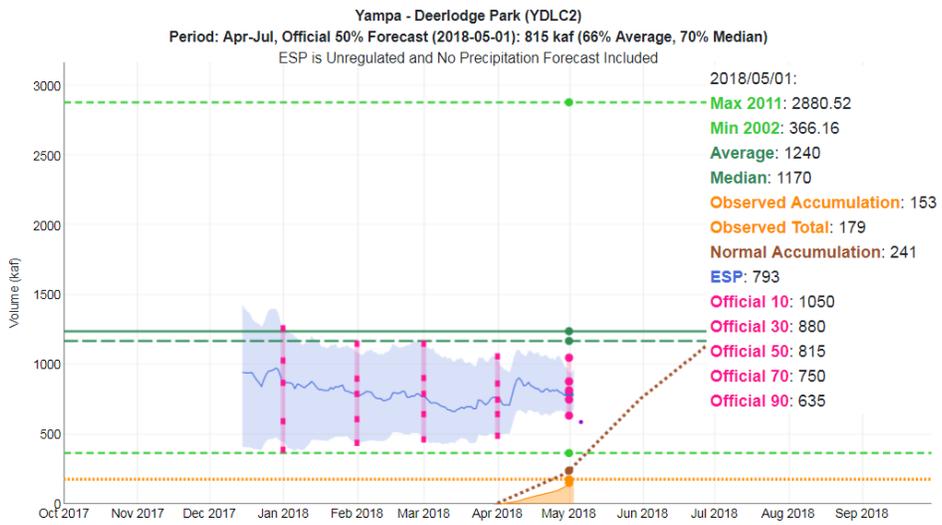


Figure 7 - Yampa River Basin at Deerlodge Park Water Supply Forecast as of May 7, 2018.

Figure 8 shows the current forecasts in relation to historic flow volumes. Figure 9 illustrates the Yampa River at Maybell plus Lily April final forecast probability (percent exceedance). For both figures the most, minimum and maximum probable values are taken from the May final Forecast.

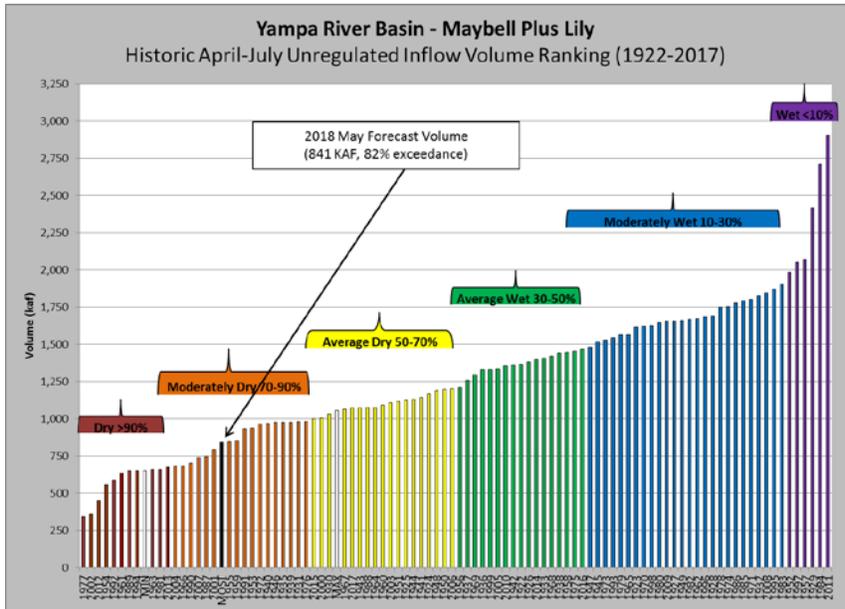


Figure 8 - Yampa River Basin (Maybell plus Lily) May final Forecast and ranked April-July unregulated inflow volume for years 1922-2017.

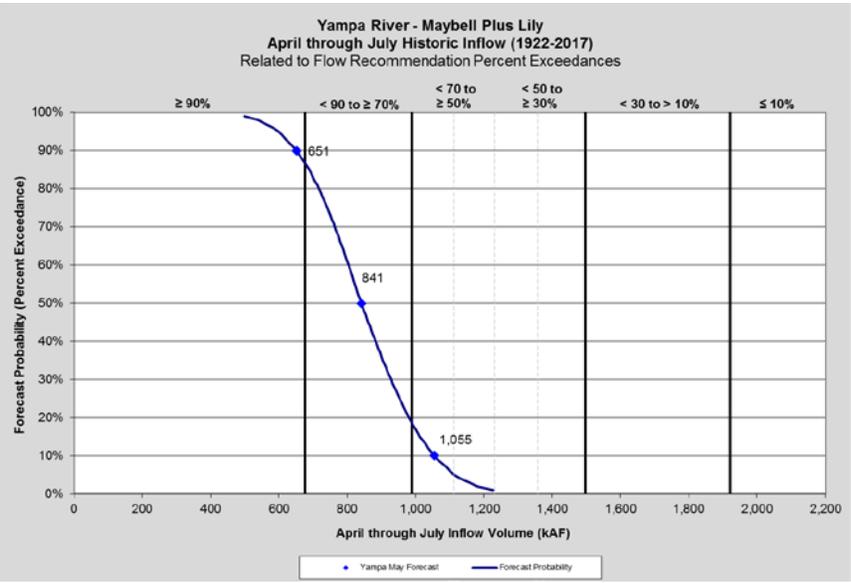


Figure 9 - Yampa River – Maybell Plus Lily May final Forecast probability (percent exceedance) and historic April-July unregulated inflow volume for years 1963-2017.

Probabilities of Flow Events for Spring 2018

The Flaming Gorge unregulated inflow and Yampa River forecasts can be classified as average dry and moderately dry, respectively. An analysis was completed to assist in the determination of appropriate flow objectives for spring and summer 2018. The ten most similar historic years for the Yampa River Basin (Maybell plus Lily) compared to the current forecast (Table 1) were analyzed assuming a normal distribution.

Table 2 presents the percent exceedance of cumulative days greater than or equal to various unregulated inflow volumes for the Yampa River (Maybell plus Lily). The current analysis indicates that it is likely Yampa River flows above 10,000 cfs will not be achieved this year.

**Table 1
Yampa River (Maybell plus Lily) – April through July Unregulated Volume
Ten Similar Years to the April 24, 2018 ESP Forecast
Thousand Acre-Feet (KAF)**

Year	April- July Unreg Inflow Volume (KAF)
MIN	651
1966	679
1990	703
2007	736
1987	746
2001	790
MOST	841
1955	845
1959	852
1991	934
1953	938
1972	966
MAX	1,055

Table 2
Spring 2018 – Days above Specific Flow Thresholds in the Yampa River
(Maybell plus Lily)
Based on the April 24, 2018 ESP Forecast
Percent Exceedance (%)

May final Forecast	% Exceed	Days above 8000 cfs	Days above 9000 cfs	Days above 10000 cfs	Days above 11000 cfs	Days above 12000 cfs	Days above 13000 cfs	Days above 14000 cfs
YAMPA	25%	14	8	2	0	0	0	0
	50%	4	1	0	0	0	0	0
	75%	2	0	0	0	0	0	0
	90%	1	0	0	0	0	0	0

Colorado Basin River Forecast Center Yampa River Analysis

The Colorado Basin River Forecast Center (RFC) calculates exceedance probabilities based on thirty-five years of historic temperature and precipitation data (1981-2015) and current hydrologic conditions to provide projections of flow. The RFC provides projections based upon (1) strict observance to the historic dataset and (2) current hydrologic conditions including SWE, flow, and soil moisture and (3) incorporation of the five-day quantitative precipitation forecast (QPF). QPF is the expected amount of forecasted precipitation.

The RFC provides a synopsis of the current seasonal outlook for the Yampa River at Deerlodge. This synopsis is provided below:

This outlook is based on flows from ESP with model states as of April 24. Month to date precipitation for April is above average in the Yampa River basin and below to near average in the Little Snake River basin. An active weather pattern has helped to improve snow and water supply conditions since the first of the month. There have been periods of warming and cooling which has resulted in periods of snowmelt at the low and mid elevations below 10,000 ft. The most significant melt has occurred over the past two days. Flows are expected to reach 4500-4700 cfs over the next two days from the most recent period of melt.

The current weather forecasts are indicating a period of above average temperatures through Sunday before another storm system impacts the region. The details of the timing, strength, and forecasted precipitation of the storm are yet to be resolved. However, temperatures should return to near normal. Flows are expected to stay elevated between 3700-5000 cfs through the end of the month with additional snowmelt before gradually decreasing.

The RFC provides updated Yampa River April through July seasonal exceedance probabilities for both the river flows and daily maximum peak flow. Table 3 presents the RFC projections of maximum peak flow based on current information. Figure 10 and Figure 11 illustrate the probabilities of the Yampa River at Deerlodge river flows exceeding certain thresholds and exceedance probabilities over the April through July spring period.

Table 3
Maximum Peak Daily Flow on the Yampa River at Deerlodge
Based on the April 24, 2018, RFC Analysis
Percent Exceedance (%)

CBRFC April 24, 2018 Projections	% Exceed	Maximu m Daily Peak (cfs)	Number of Days to Peak from 04/24/18	Number of Days Above 4,000 cfs	Number of Days above 5,000 cfs	Number of Days above 6,000 cfs	Number of Days above 8,000 cfs	Number of Days above 10,000 cfs	Number of Days above 12,000 cfs
YAMPA	10%	12,748	47	57	45	40	19	9	0
	25%	10,820	37	51	39	27	10	3	0
	50%	9,198	30	43	30	18	3	0	0
	75%	7,823	25	40	20	10	0	0	0
	90%	7,184	7	30	15	8	0	0	0

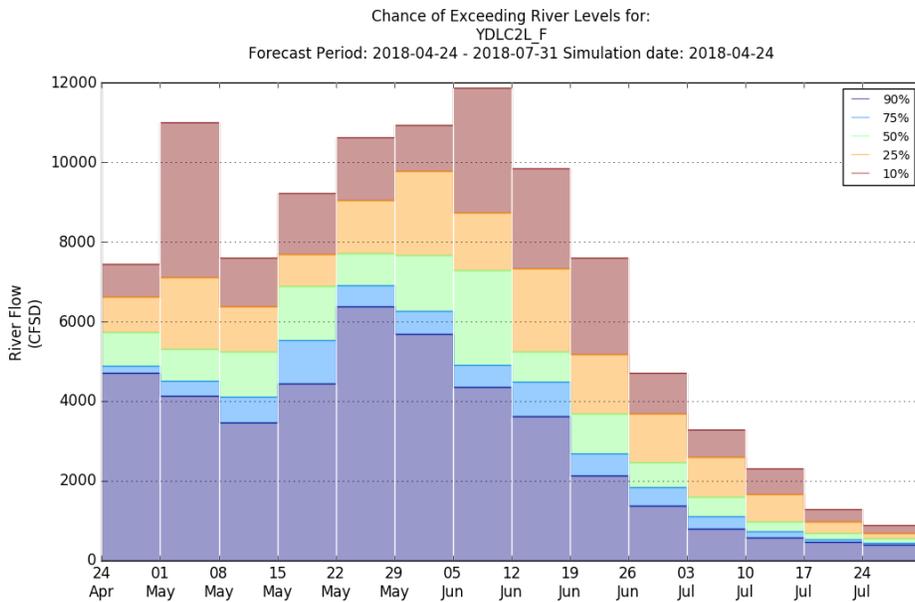


Figure 10 - RFC April 24, 2018 projection of Yampa River at Deerlodge flows exceeding thresholds for various percent exceedance at a weekly time step for the 2018 April through July period.

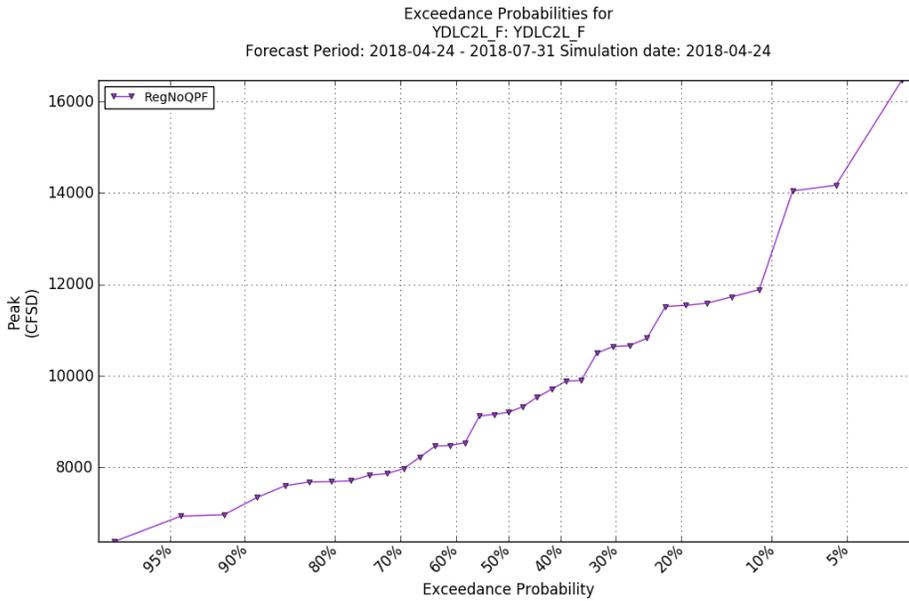


Figure 11 - CBRFC April 24, 2018 projection of Yampa River at Deerlodge maximum peak daily flow exceedance probabilities based on current hydrologic conditions and historical precipitation and temperature.

15-Day Yampa Streamflow Forecast

The CBRFC is indicating, based off of current modeling that the Yampa River will peak at some time between May 14 and May 17. The following, Figure 12 illustrates the forecasted flow values for the Yampa River, May 7 through May 17, 2018. The projected average flow values for each day in the Yampa at Deerlodge May 8 through May 22, 2018 are provided in .

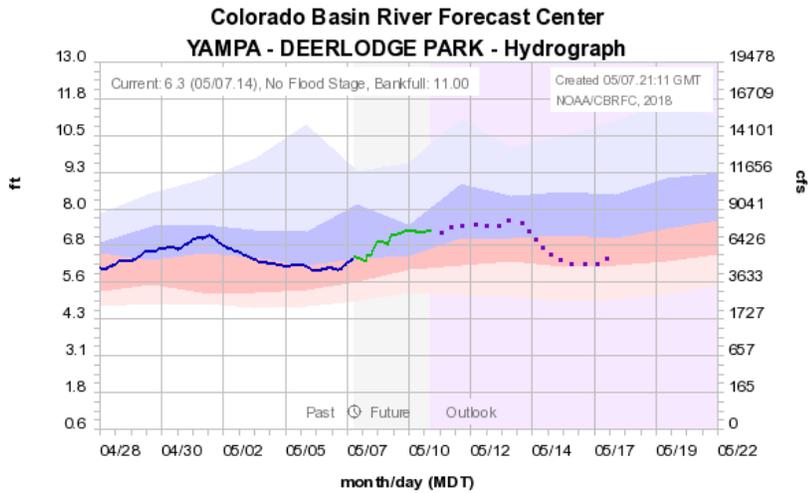


Figure 12 - Streamflow forecast for the Yampa River, May 7 - May 17, 2018.

Table 4
Deterministic forecast flow for Yampa-Derlodge, May 8 - May 22, 2018.
Based on May 7, 2018 CBRFC Modeling

Date	Average Daily Flow (cfs)
5/8/2018	5327
5/9/2018	6635
5/10/2018	7368
5/11/2018	7387
5/12/2018	7846
5/13/2018	7875
5/14/2018	8089
5/15/2018	6719
5/16/2018	5261
5/17/2018	4979
5/18/2018	5546
5/19/2018	5904
5/20/2018	5494
5/21/2018	5193
5/22/2018	5097

Larval Trigger Study Plan Projected Operations

Previous to the implementation of the ROD, the U.S. Fish and Wildlife Service issued a Biological Opinion in 1992 that timed releases from Flaming Gorge to occur during the spring peak of the Yampa River. Under the ROD, Flaming Gorge releases are timed during the Yampa River spring peak and immediate post peak.

The Larval Trigger Study Plan (LTSP) experimental protocol alters Flaming Gorge releases to occur after razorback sucker larvae have been observed in the Green River below Flaming Gorge Dam. This modification in timing of spring peak releases alters projected operations from Flaming Gorge as compared against historic releases.

Table 4 outlines the LTSP matrix used to determine the peak flow measured at Jensen, targeted study wetlands, number of days exceeded for each hydrologic classification.

Table 5
Larval Trigger Study Plan Table 2 Matrix

TABLE 2. Matrix to Be Used in Studying the Effectiveness of a Larval Trigger

Peak Flow (x) as Measured at Jensen, Utah	Proposed Study Wetlands ^(a, b)	Number of Days (x) Flow to Be Exceeded and Corresponding Hydrologic Conditions ^(c)		
		1 ≤ x < 7	7 ≤ x < 14	x ≥ 14
8,300 ≤ x < 14,000 cfs	Stewart Lake (f), Above Brennan (f), Old Charley Wash (s)	Dry	Moderately dry	Moderately dry and average (below median)
14,000 ≤ x < 18,600 cfs	Same as previous plus Thunder Ranch (f), Bonanza Bridge (f), Johnson Bottom (s), Stirrup (s), Leota 7 (s)	Average (below median)	Average (below median)	Average (below median)
18,600 ≤ x < 20,300 cfs	Same as previous	Average (above median)	Average (above median)	Average (above median)
20,300 ≤ x < 26,400 cfs	Same as previous plus Baeser Bend (s), Wyasket (s), additional Leota units (7a and 4), Sheppard Bottom (s)	Moderately wet	Moderately wet	Moderately wet
x ≥ 26,400 cfs	Same as previous	Wet	Wet	Wet

(a) f = flow-through wetland, s = single-breath wetland

(b) Up to eight wetlands would be sampled in a given year with the three in the lowest flow category being sampled in all years.

(c) Refer to Table 1 for exceedance percentages and peak flow recommendations for each hydrologic condition. Note that the hydrologic conditions presented are the driest that could support a particular combination of peak flow magnitude and duration. For any combination, wetter hydrology could also support an experiment.

Record of Decision Spring Flow Objectives

This hydrologic update provides information regarding current conditions and how it relates to the Operating Plan detailed in the 2005 Flaming Gorge Final Environmental Impact Statement (FEIS) in Section 2.5.3.1. The operating plan is to describe the current hydrologic classification of the Green River and Yampa River Basins, including the most probable runoff patterns for the two basins. The operating plan is also to identify the most likely Reach 2 flow magnitudes and

durations that are to be targeted for the upcoming spring release. It further specifies that "[b]ecause hydrologic conditions often change during the April through July runoff period; the operations plan would contain a range of operating strategies that could be implemented under varying hydrologic conditions. Flow and duration targets for these alternate operating strategies would be limited to those described for one classification lower or two classifications higher than the classification for the current year."

The potential classifications for 2018 are as follows:

Average (Above Median) Classification

The differences between the hydrology in the Upper Green and Yampa River Basins is extreme. Yampa River flows are not expected to provide the necessary days above 10,000 cfs to obtain the moderately wet classification targets. It is likely that the average (above median) classification will prevail.

The peak flow as measured at Jensen, Utah, would correspond with the average (above median) hydrologic condition with targeted flows between 18,600 and 20,300 cfs for a period between 1 to ≥14 days in Reach 2. These flows provide connection at the Stewart Lake, Above Brennan, Old Charley Wash, Thunder Ranch, Bonanza Bridge, Johnson Bottom, Stirrup and Leota 7 floodplains.

ROD spring flow objectives for average (above median) wet years are:

Table 6 – Average (Above Median) Spring Flow Objectives

Reach	Spring Peak Magnitude (cfs)	Spring Peak Duration
Reach 1	≥ 4,600 cfs	That necessary to achieve duration target in Reach 2
Reach 2	≥ 18,600 cfs in 50% of average years	Two weeks (i.e. 14 days) in 25% of all average years
	≥ 8,300 cfs in 50% of average years	One week (i.e. 7 days) in 50% of average years

Flow Recommendations and FEIS

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Average (Below Median) Classification

The differences between the hydrology in the Upper Green and Yampa River Basins is extreme. Yampa River flows are not expected to provide the necessary days above 10,000 cfs to obtain

the moderately wet classification targets. It is likely that the average (above median) classification will prevail.

The peak flow as measured at Jensen, Utah, would correspond with the average (above median) hydrologic condition with targeted flows between 18,600 and 20,300 cfs for a period between 1 to ≥14 days in Reach 2. These flows provide connection at the Stewart Lake, Above Brennan, Old Charley Wash, Thunder Ranch, Bonanza Bridge, Johnson Bottom, Stirrup and Leota 7 floodplains.

ROD spring flow objectives for average (above median) wet years are:

Table 7 – Average (Above Median) Spring Flow Objectives

Reach	Spring Peak Magnitude (cfs)	Spring Peak Duration
Reach 1	≥ 4,600 cfs	That necessary to achieve duration target in Reach 2
Reach 2	≥ 18,600 cfs in 50% of average years	Two weeks (i.e. 14 days) in 25% of all average years
	≥ 8,300 cfs in 50% of average years	One week (i.e. 7 days) in 50% of average years

Flow Recommendations and FEIS

Moderately Dry Classification

The differences between the hydrology in the Upper Green and Yampa River Basins is extreme. Yampa River flows are not expected to provide the necessary days above 10,000 cfs to obtain the moderately wet classification targets. It is likely that the average (above median) classification will prevail.

The peak flow as measured at Jensen, Utah, would correspond with the average (above median) hydrologic condition with targeted flows between 18,600 and 20,300 cfs for a period between 1 to ≥14 days in Reach 2. These flows provide connection at the Stewart Lake, Above Brennan, Old Charley Wash, Thunder Ranch, Bonanza Bridge, Johnson Bottom, Stirrup and Leota 7 floodplains.

ROD spring flow objectives for average (above median) wet years are:

Table 8 – Average (Above Median) Spring Flow Objectives

Reach	Spring Peak Magnitude (cfs)	Spring Peak Duration
Reach 1	≥ 4,600 cfs	That necessary to achieve duration target in Reach 2
Reach 2	≥ 18,600 cfs in 50% of average years	Two weeks (i.e. 14 days) in 25% of all average years
	≥ 8,300 cfs in 50% of average years	One week (i.e. 7 days) in 50% of average years

Flow Recommendations and FEIS

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