RECLAMATION
*Managing Water in the West*

# Flaming Gorge Technical Working Group

## May 9, 2017 Hydrology Summary

Heather Patno

For the purposes of discussions related to implementing the ROD in 2017, 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 2016. The April 1, 2017 midmonth forecast was 2,260,000 acre-feet for Flaming Gorge. The hydrologic classification will be wet (<10% exceedance) for spring 2017.

The combined April through July forecast of the Yampa River at Maybell and Little Snake at Lily is 1,080,000 acre-feet. This forecast would fall into the average (above median) hydrologic classification of the ROD.

Snow water equivalent (SWE) as of May 9, 2017, for the Upper Green River and Yampa/White River Basins are 190 and 77 percent of median, respectively. Flaming Gorge SWE is similar to 1986 and 1997, while Deerlodge SWE is similar to 1990 and 2000. The Tower snotel site, used as a reference point for Yampa snowpack and runoff, currently has 43.2 inches of SWE (84 percent of median). On May 9, Tower SNOTEL measured SWE inches of:

- 1990 = 47.3 in; Yampa 703 kaf obs spring (55%)
- 2000 = 39.5 in; Yampa 1,005 kaf obs spring (79%)

## Basin Hydrology

### *Green River Basin Hydrology*

The May 1, 2017, final forecast of April through July unregulated inflow (current forecast) for Flaming Gorge Reservoir is 2,260,000 acre-feet (AF) (231% of 30-year average). This forecast falls at < 5% exceedance based on the historic unregulated inflow record (1963-2016).

Figure 1 illustrates the Upper Green River SWE as of May 9, 2017, and compares it against water years 1986 and 1997. Figure 2 indicates that the forecast for Flaming Gorge Reservoir has remained stable and the May 1, 2017, final forecast remained unchanged at 2,260 kaf from

two weeks ago. The May 9 raw ESP most probable value of 2.27 maf is consistent with the forecast value of 2.26 maf. The CBRFC forecast includes uncertainty in modeled snow and soil moisture states that are reflected in the current forecast.

Historic year unregulated inflow volumes that compare with current snowpack are 1986 with total inflow into Flaming Gorge of 2,222 kaf (maximum historic year) and 1997 with total inflow into Flaming Gorge of 1,668 kaf (170 percent of average).

Figure 3 illustrates the current forecast in relation to the historic unregulated inflow volumes. Figure 4 illustrates Flaming Gorge Reservoir May final forecast probability (percent exceedance).

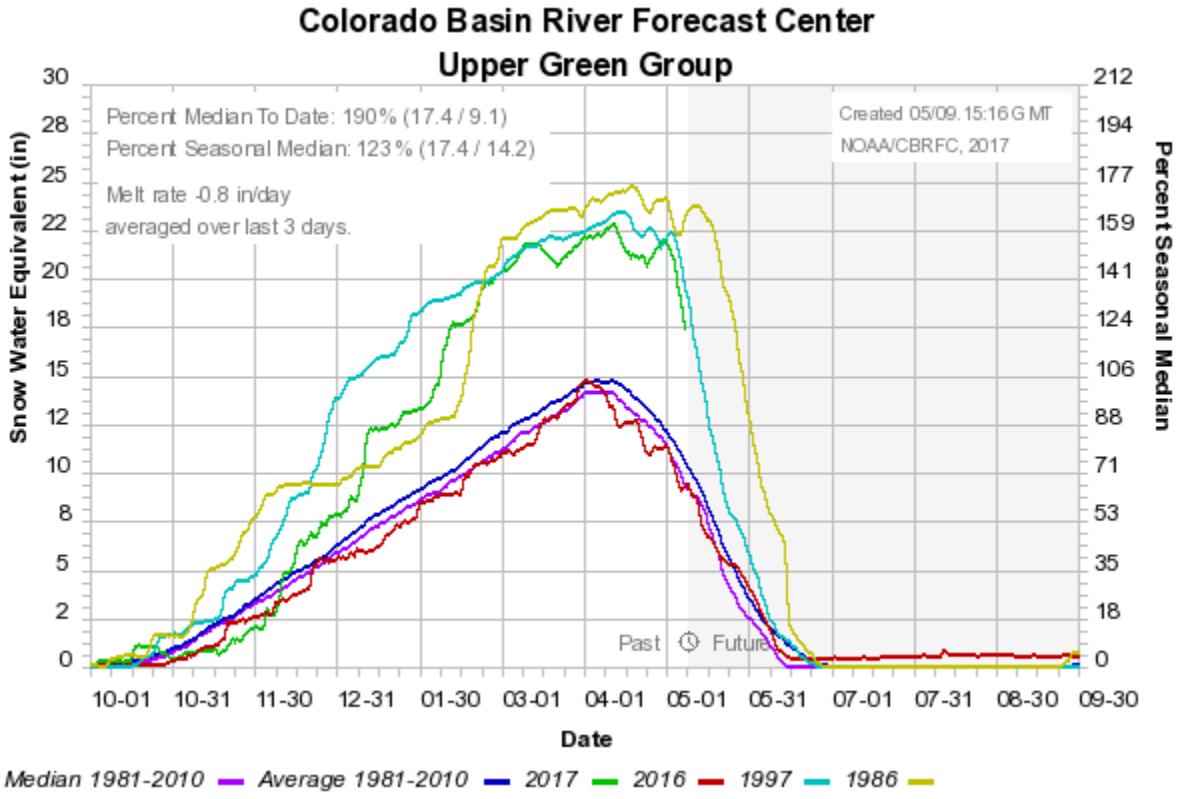


FIGURE 1. Upper Green River Basin Snotel Tracking. 1981-2010 percent of median compared against 2017 YTD Snow Water Equivalent (SWE) and 1986, 1997 and 2016 percent of average SWE

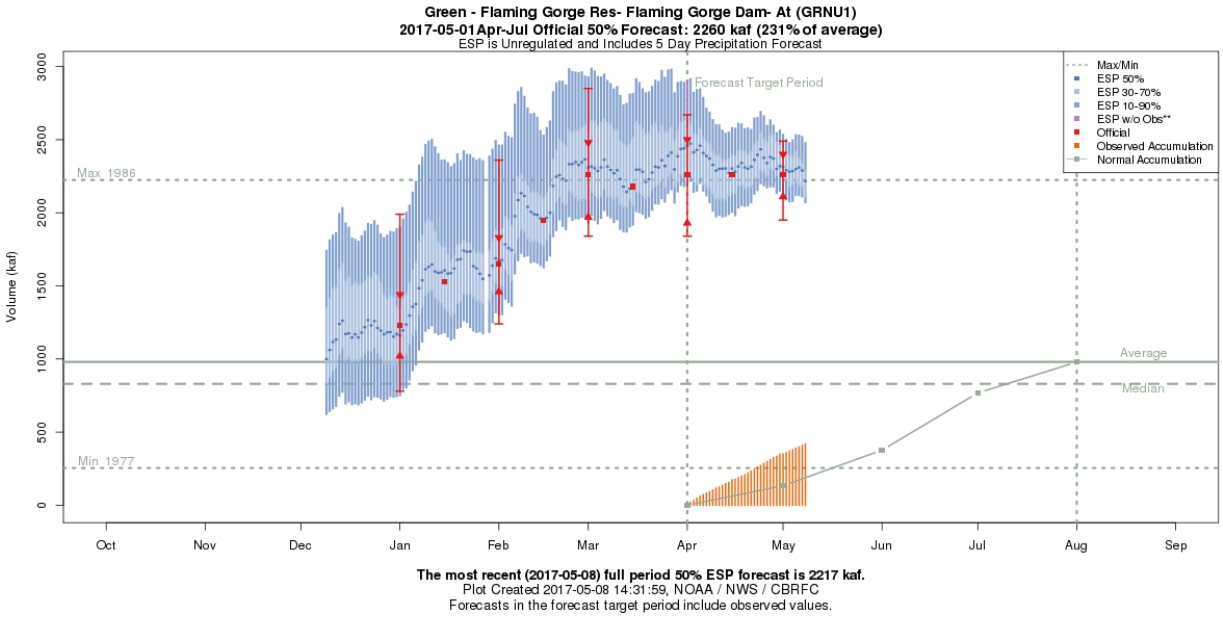


FIGURE 2. Upper Green River Basin Water Supply Forecast as of May 9, 2017.

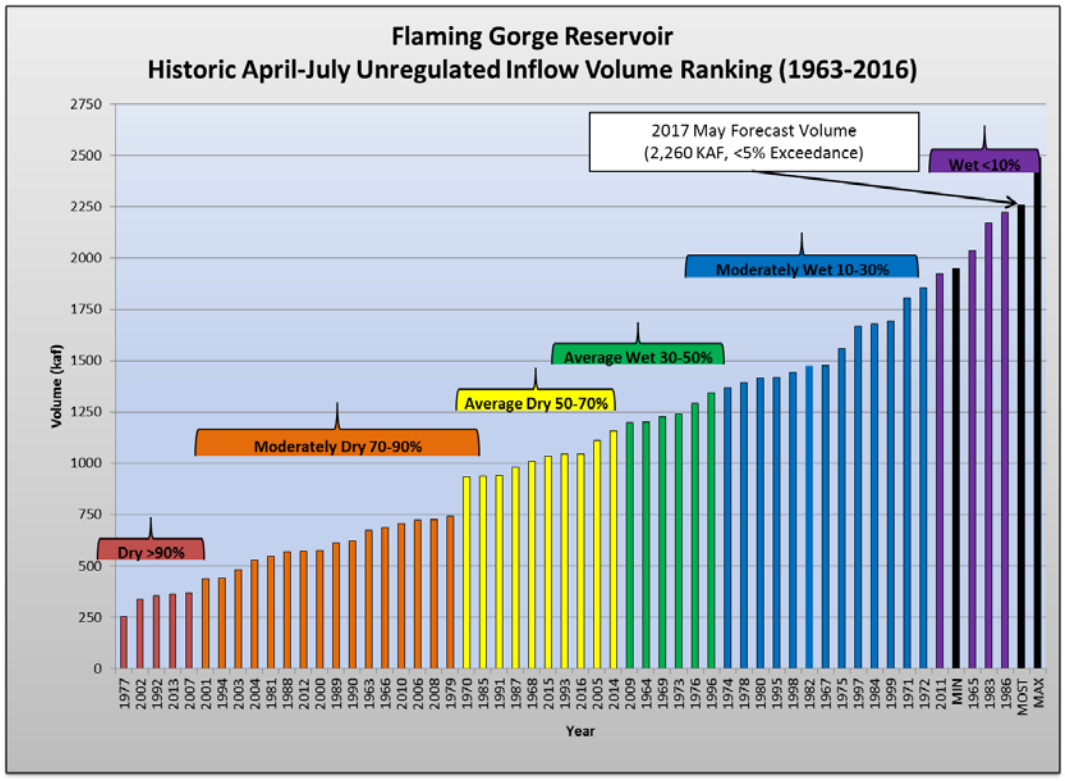


FIGURE 3. Flaming Gorge Reservoir May 1, 2017 forecast and ranked historic April-July unregulated inflow volume for years 1963-2016

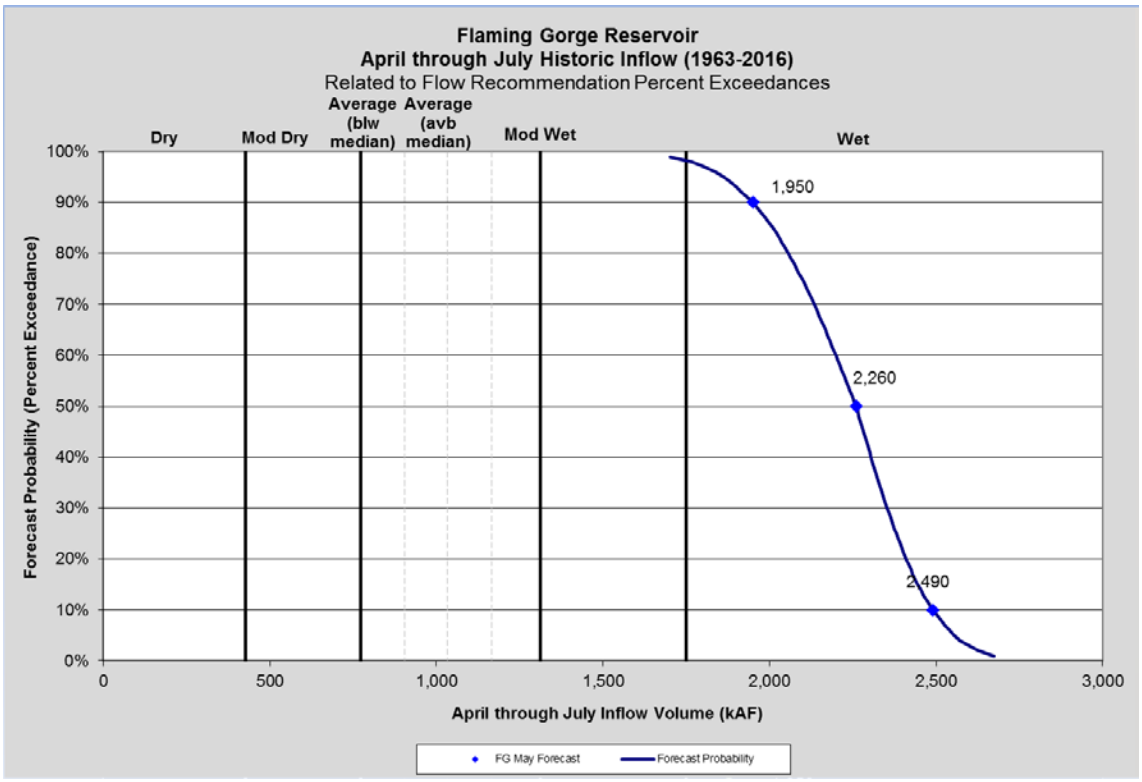


FIGURE 4. Flaming Gorge Reservoir May final forecast probability (percent exceedance) and historic April-July unregulated inflow volume for years 1963-2016

## *Yampa River Basin Hydrology*

The combined current forecast for the Little Snake at Lily plus Yampa River at Maybell is 1,080,000 AF (87% of 30-year average). This forecast falls at approximately 63% exceedance based on a ranking of the historic record (1922-2016).

Figure 5 illustrates the Yampa River at Deerlodge Park SWE as of May 9, 2017, and compares it against water years 1990 and 2001. Figure 6 indicates that the forecast for the Yampa River at Deerlodge is declining and the May 9, 2017, final forecast decreased from 1,080 kaf to 989 kaf.[1]

Figure 7 below shows the current forecast in relation to historic flow volumes. Figure 8 illustrates the Yampa River at Maybell plus Lily April final forecast probability (percent exceedance).

[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.

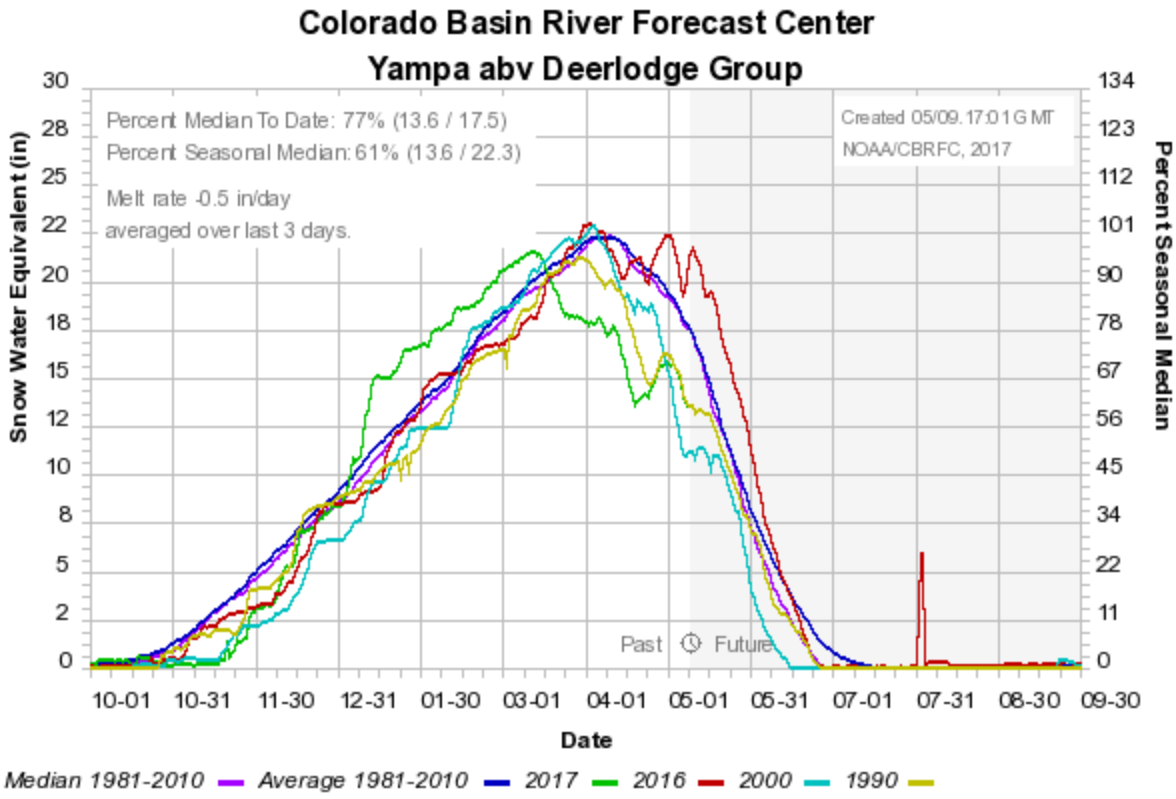


FIGURE 5. Yampa River above Deerlodge SNOTEL Group. 1981-2010 percent of average SWE compared against 2017 YTD, and analog years 1990, 2001, and 2016 percent of median SWE

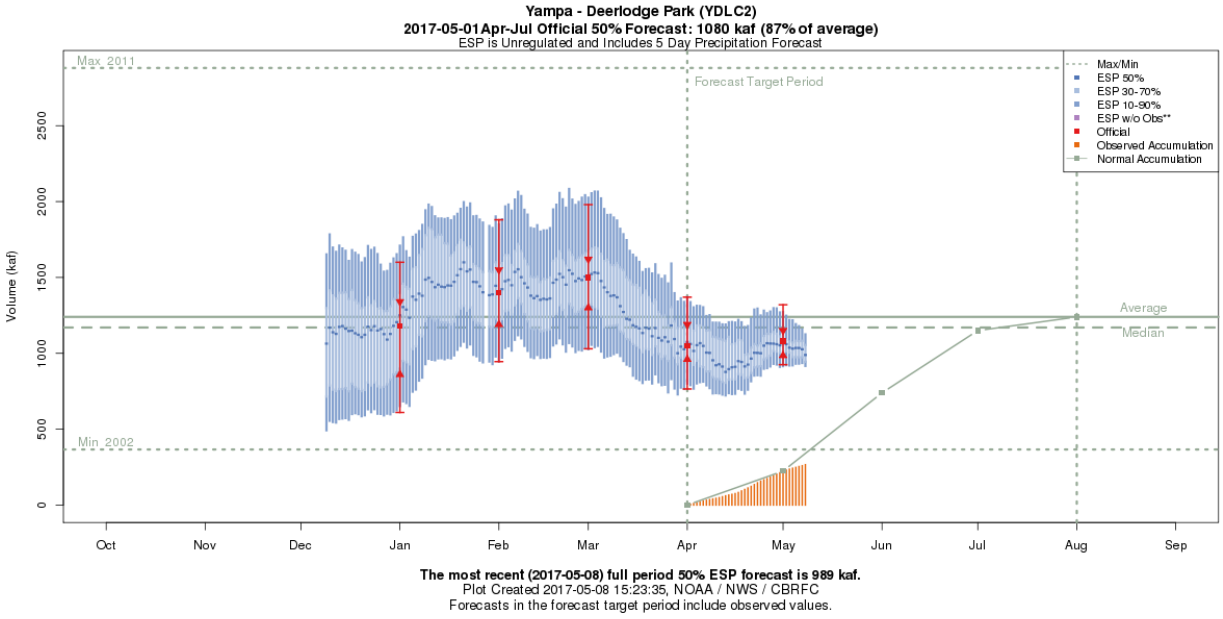


FIGURE 6. Yampa - Deerlodge Park Water Supply Forecast as of May 9, 2017.

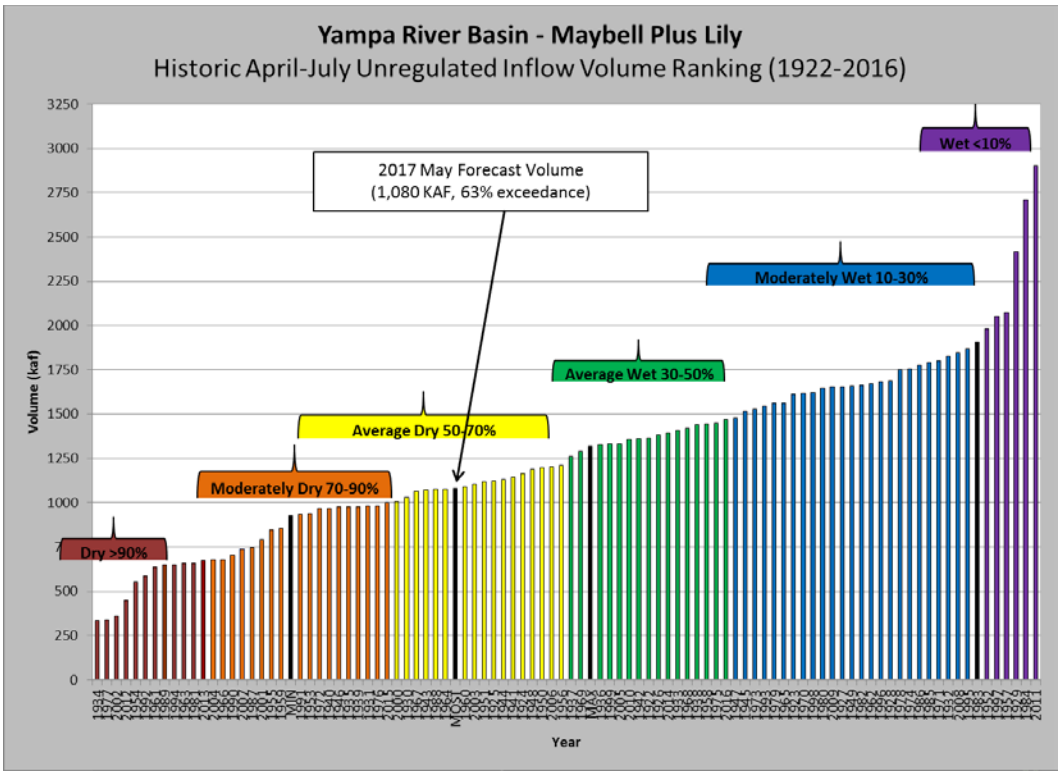


FIGURE 7. Yampa River Basin (Maybell plus Lily) April final forecast and ranked April-July unregulated inflow volume for years 1922-2016

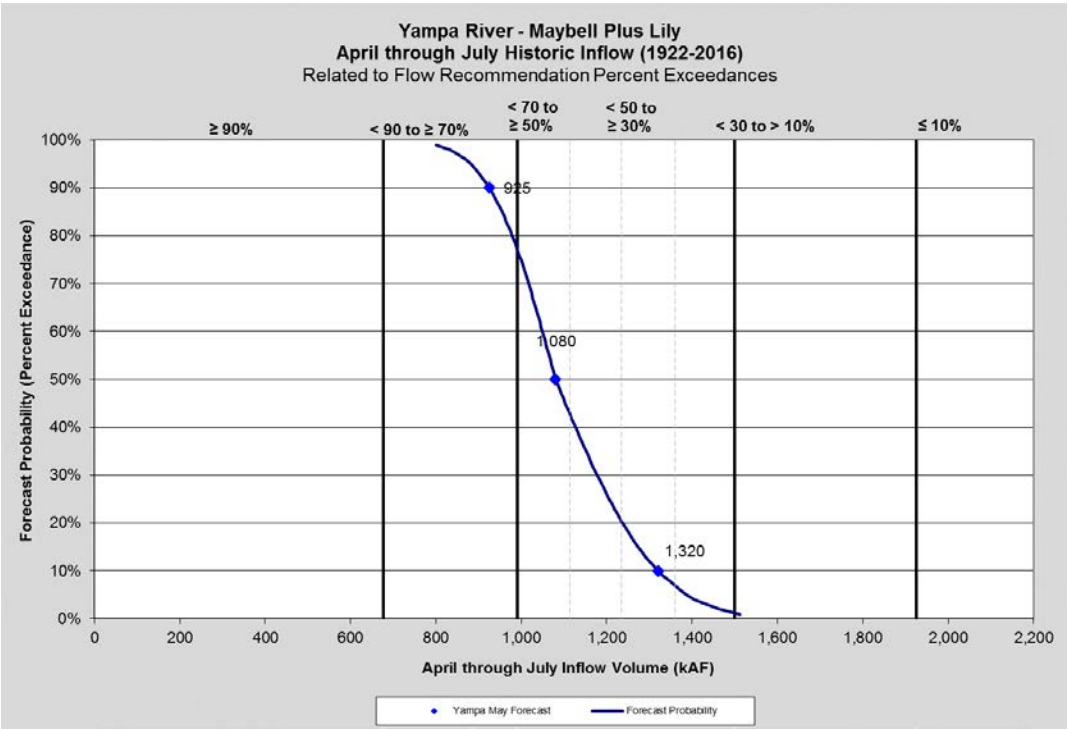


FIGURE 8. Yampa River – Maybell Plus Lily April final forecast probability (percent exceedance) and historic April-July unregulated inflow volume for years 1963-2016

On May 9 around noon, the Yampa River is flowing around 7,400 cfs and expected to increase to around 8,800 cfs on May 11-12, 2017. Figure 9 below shows the past 30 days of observed Yampa River flows and the forecasted 10 days of flows as measured at Deerlodge Park. The follow figure, Figure 10, indicates the 30 days of observed and forecast 10 days of flows measured on the Green River at Jensen, Utah, depending upon the current release strategy at Flaming Gorge Dam.

Figures 11 and 12 display the historic releases and observed hydrology for hydrologic years 1990 and 2000, the similar years to Yampa River hydrology based on current snowpack in the Yampa River Basin. Both 1990 and 2000 Yampa River hydrology peaked toward the end of May into June around Memorial Day, or the average historic peak on the Yampa. Early indications are that this year may be similar, although the Tower snow water equivalent on May 9 in 1990 was greater than the current observation. Additionally, the observed runoff volume in 1990 (703 kaf, 55% of average) was less than 2000 (1,005 kaf, 79% of average) or years with lower overall snowpack.

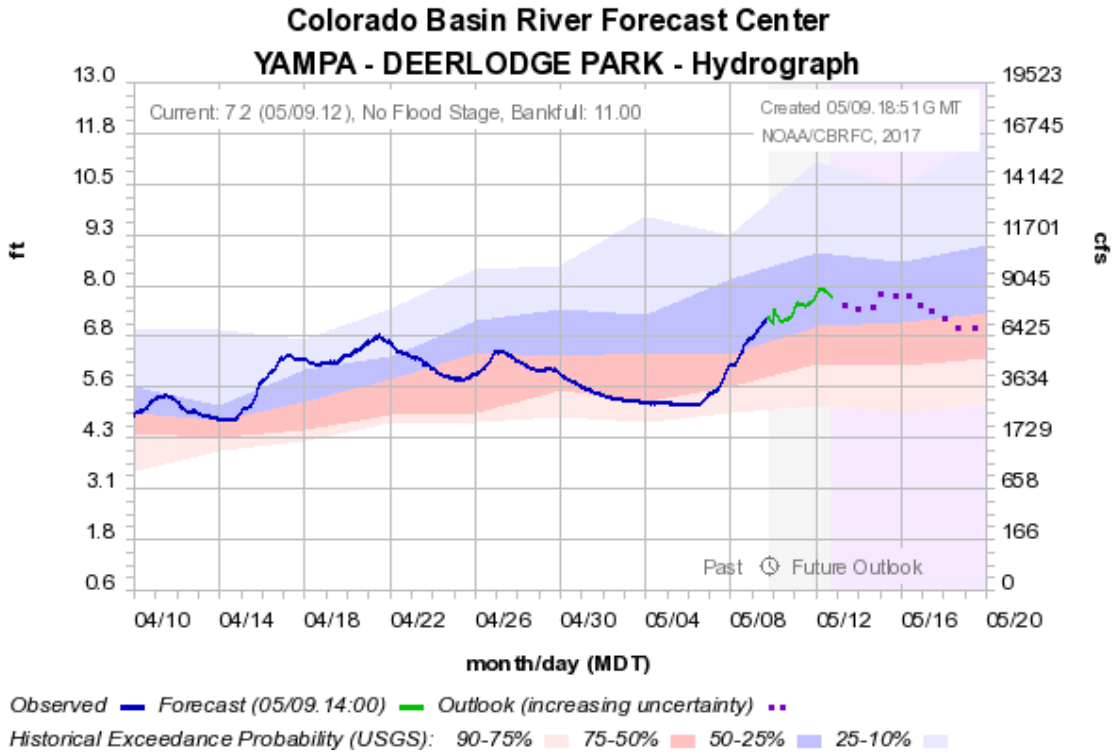


FIGURE 9. Yampa River – Maybell Plus Lily April final forecast probability (percent exceedance) and historic April-July unregulated inflow volume for years 1963-2016

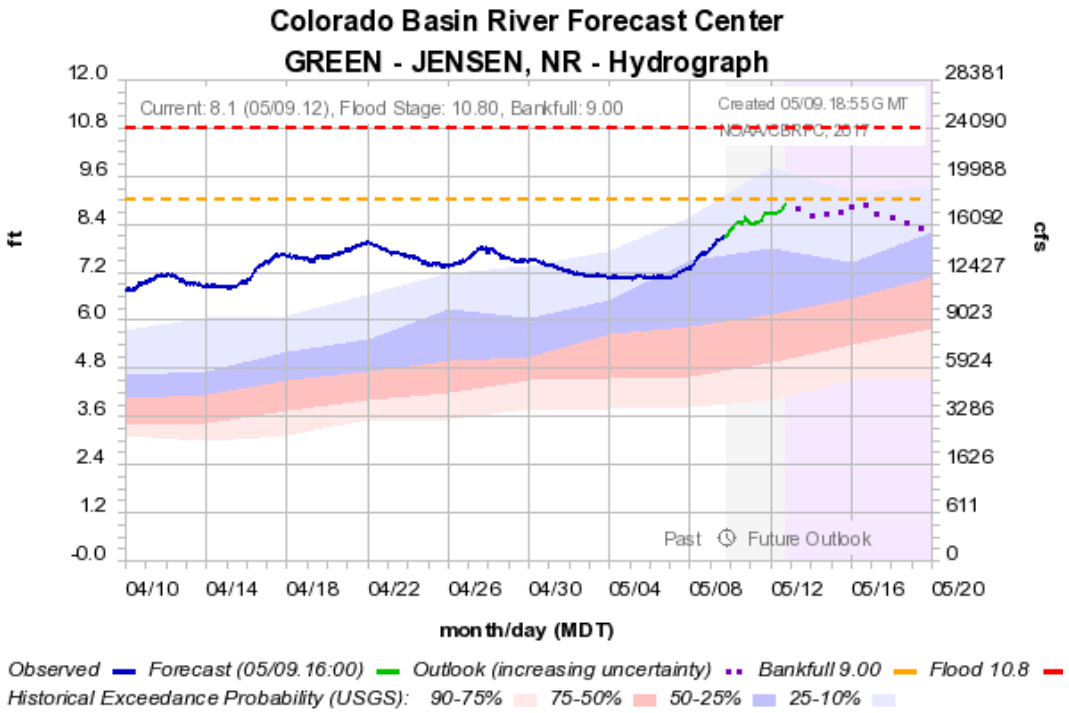


FIGURE 10. Yampa River – Maybell Plus Lily April final forecast probability (percent exceedance) and historic April-July unregulated inflow volume for years 1963-2016

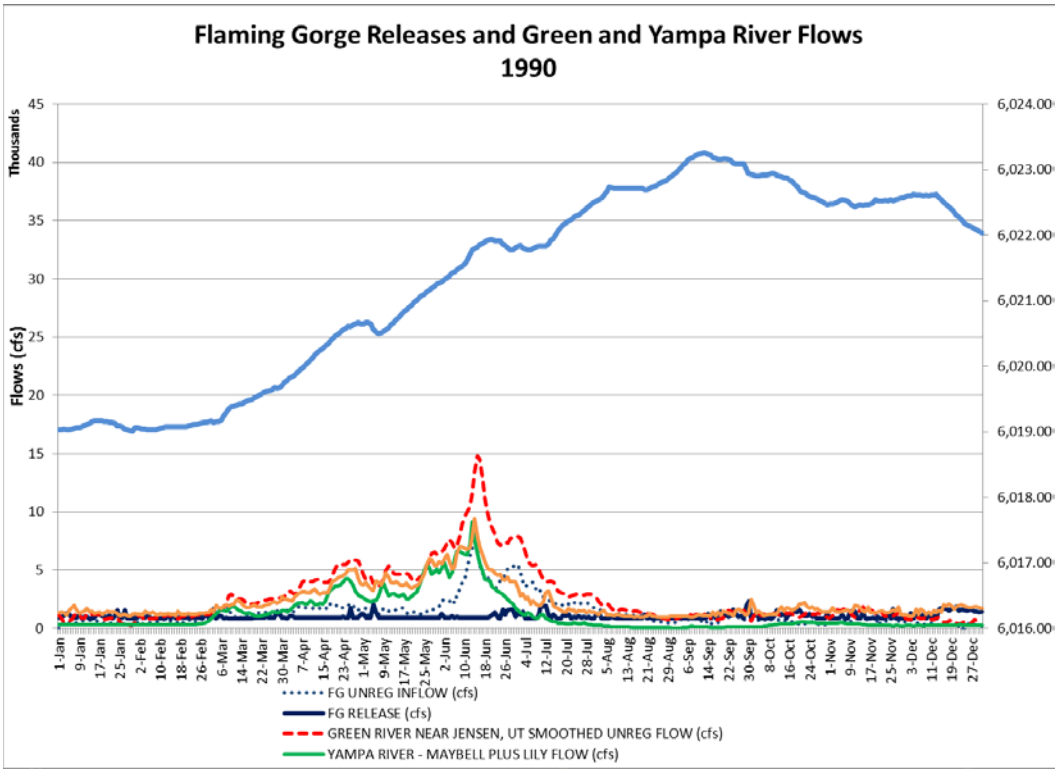


FIGURE 11. Yampa River – Maybell Plus Lily April final forecast probability (percent exceedance) and historic April-July unregulated inflow volume for years 1963-2016

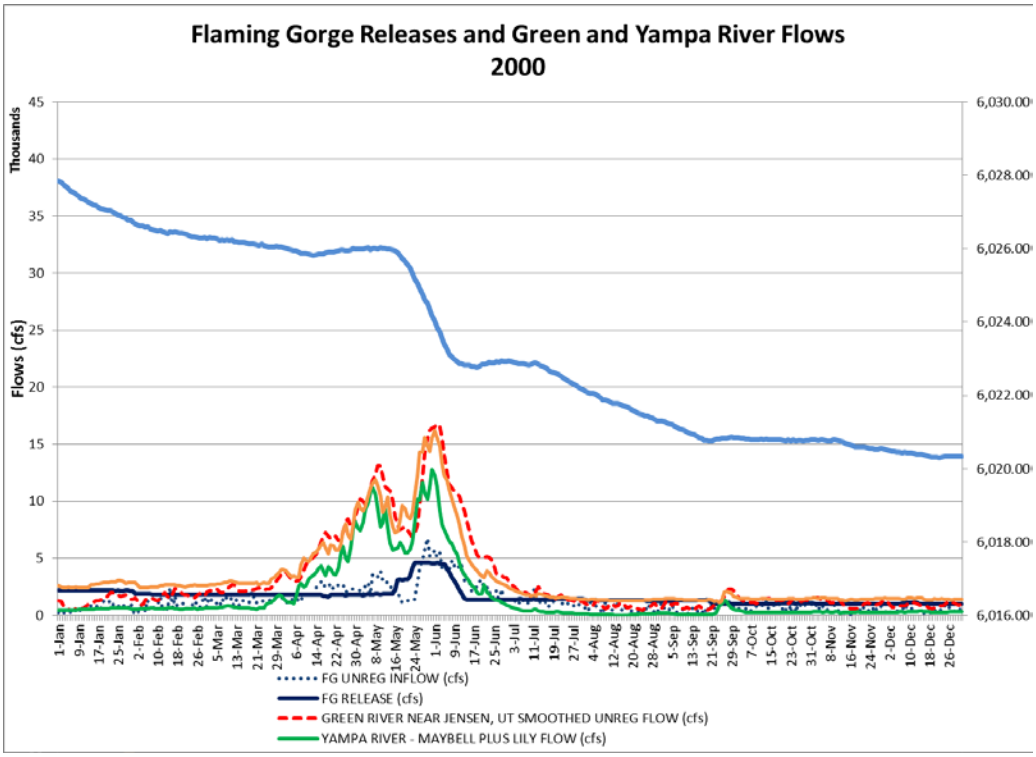


FIGURE 12. Yampa River – Maybell Plus Lily April final forecast probability (percent exceedance) and historic April-July unregulated inflow volume for years 1963-2016

## *Probabilities of Flow Events for Spring 2017*

The Flaming Gorge unregulated inflow and Yampa River forecasts are wet and average (below median), respectively. The Green River Basin continues to trend wetter, while the Yampa River Basin is trending drier. An analysis was completed to assist in the determination of appropriate flow objectives for spring and summer 2017. The Flaming Gorge forecast is so high that ten similar between the minimum and maximum forecasts are unavailable. 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 flow levels at Yampa River (Maybell plus Lily). The current analysis indicates that it is likely Yampa River flows above 10,000 cfs necessary to meet the wet or moderately wet duration targets in Reach 2 will not be achieved this year.

**Table 1**
**Yampa River (Maybell plus Lily) – April through July Unregulated Volume**
**Ten Similar Years to the May 9, 2017 Forecast**
**Thousand Acre-Feet (KAF)**

| Year | April-July Unreg Inflow Volume (KAF) |
|---|---|
| MIN | 925 |
| 1930 | 1,031 |
| 1967 | 1,062 |
| 1943 | 1,071 |
| 1988 | 1,074 |
| 1964 | 1,075 |
| MOST | 1,080 |
| 1960 | 1,089 |
| 2003 | 1,108 |
| 1951 | 1,116 |
| 1925 | 1,121 |
| 1944 | 1,131 |
| MAX | 1,320 |

**Table 2**
**Spring 2017 – Days above Specific Flow Thresholds in the Yampa River (Maybell plus Lily)**
**Based on the May 1, 2017 Forecast**
**Percent Exceedance (%)**

| May 1, 2017 Forecast | % Exceed | Days above 6000 cfs | Days above 8000 cfs | Days above 10000 cfs | Days above 11000 cfs | Days above 12000 cfs | Days above 13000 cfs | Days above 16000 cfs |
|---|---|---|---|---|---|---|---|---|
| YAMPA | 25% | 39 | 20 | 11 | 9 | 5 | 3 | 0 |
| | 50% | 38 | 20 | 5 | 3 | 2 | 2 | 0 |
| | 75% | 36 | 13 | 2 | 1 | 0 | 0 | 0 |
| | 90% | 32 | 10 | 1 | 0 | 0 | 0 | 0 |

# Colorado Basin River Forecast Center Yampa River Analysis

The Colorado Basin River Forecast Center (RFC) calculates percent exceedance based on thirty years of historic temperature and precipitation data (1981-2010) using a modified Monte Carlo method to provide projections of flow. The RFC provides projections based upon (1) strict observance to the historic dataset and (2) incorporation of the five-day quantitative precipitation forecast (QPF). QPF is the expected amount of melted precipitation over the five-day climate forecast period.

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 May 9.*
>
> *A low pressure system will impact the basin today and tomorrow. Cooler temperatures and precipitation are possible through Wednesday. Warmer and drier weather will return for late in the week through weekend. Models are currently indicating another weather system to impact the area early next week but the details are yet to be resolved.*
>
> *The current flow at Yampa River-Deerlodge is 7,440 cfs and the 10 day streamflow forecasts are indicating flows may reach ~8800 cfs over the next 10 days. ESP guidance is indicating that flows will return to levels similar or slightly higher than current forecasts. However, the peak may occur in the next 10 days if there is significant precipitation.*

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 based on current information. Figures 13 and 14 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 May 9, 2017, RFC Analysis**
**Percent Exceedance (%)**

| CBRFC May 9, 2017 Projections | % Exceed | Maximum Daily Peak (cfs) | Number of Days to Peak from 04/01/17 | Number of Days Above 10,000 cfs | Number of Days above 14,000 cfs | Number of Days above 16,000 cfs |
|---|---|---|---|---|---|---|
| YAMPA | 10% | 11,610 | 26 | 3 | 0 | 0 |
| | 25% | 10,050 | 21 | 1 | 0 | 0 |
| | 50% | 9,044 | 14 | 0 | 0 | 0 |
| | 75% | 8,719 | 7 | 0 | 0 | 0 |
| | 90% | 8,612 | 7 | 0 | 0 | 0 |

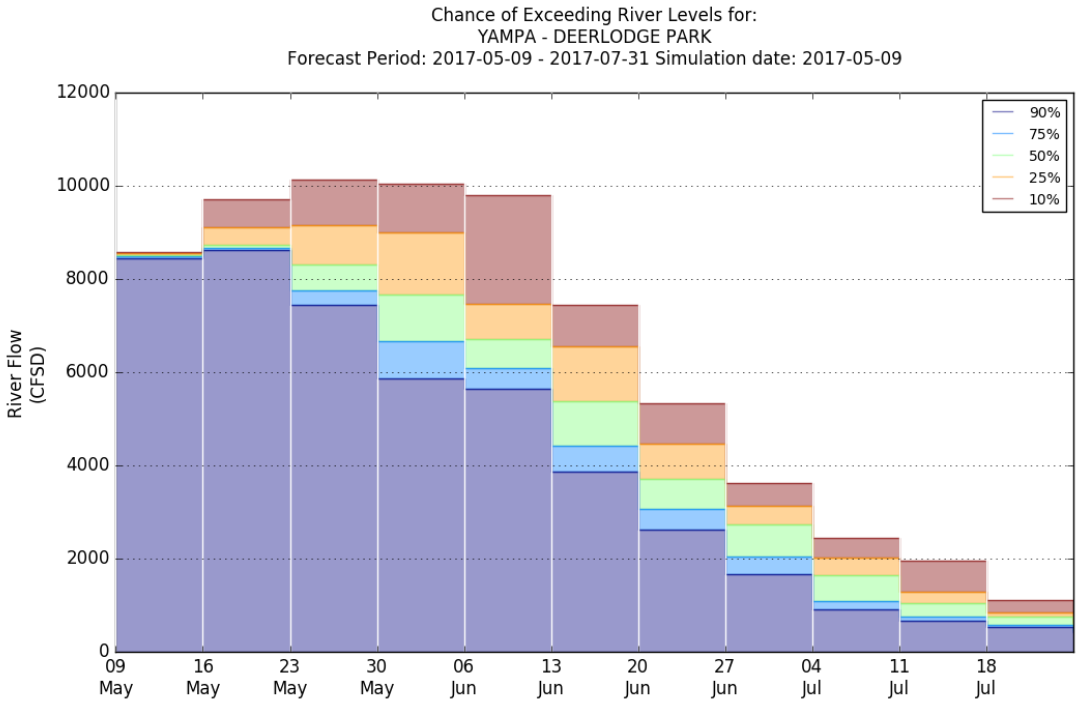


FIGURE 13. RFC May 4, 2017 projection of Yampa River at Deerlodge flows exceeding thresholds for various percent exceedance for the 2017 April through July spring period.

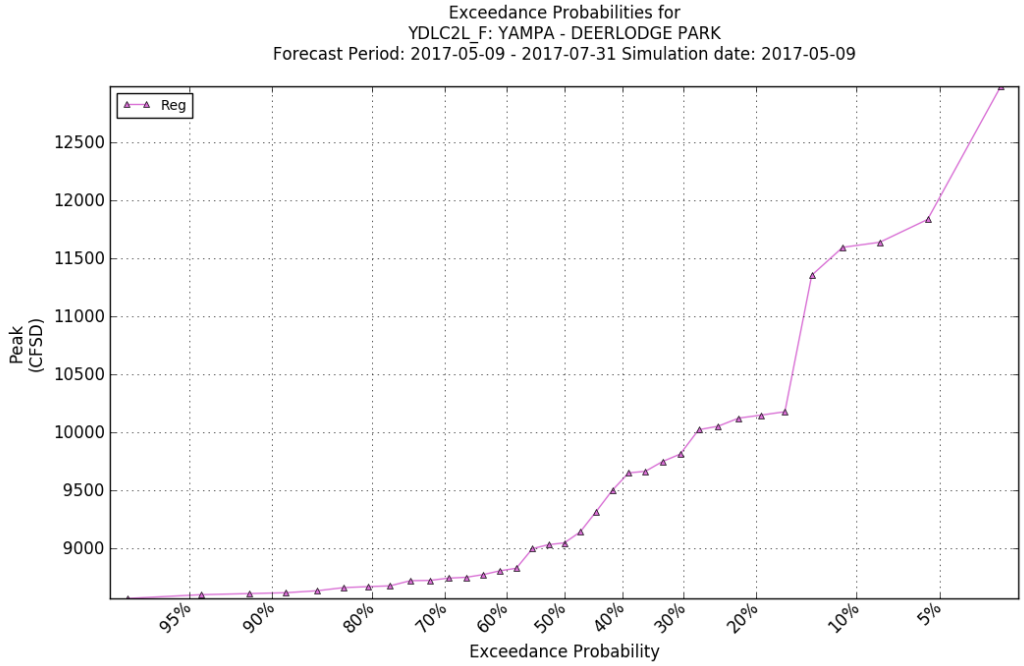


FIGURE 14. RFC May 9, 2017 projection of Yampa River at Deerlodge flow exceeding thresholds for based on the historic observed, simulation of historic climate with current initial conditions and simulation of historic climate including the ten-day QPF with initial conditions.

## *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 4**
**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] | | |
|---|---|---|---|---|
| | | $1 \leq x < 7$ | $7 \leq x < 14$ | $x \geq 14$ |
| $8,300 \leq x < 14,000$ cfs | Stewart Lake (f), Above Brennan (f), Old Charley Wash (s) | Dry | Moderately dry | Moderately dry and average (below median) |
| $14,000 \leq x < 18,600$ 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) |
| $18,600 \leq x < 20,300$ cfs | Same as previous | Average (above median) | Average (above median) | Average (above median) |
| $20,300 \leq x < 26,400$ 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 |
| $x \geq 26,400$ cfs | Same as previous | Wet | Wet | Wet |

(a) f = flow-through wetland, s = single-breach 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 2017 are as follows:

## *Wet*

If the April through July unregulated inflow into Flaming Gorge Reservoir remains above 1,751,000 AF the hydrological classification would be wet. It is not recommended to operate Flaming Gorge within the wet hydrologic classification.

The ROD spring flow objectives for wet years are:

**Table 5 – Wet Spring Flow Objectives**

| Reach | Spring Peak Magnitude (cfs) | Spring Peak Duration |
|---|---|---|
| Reach 1 | ≥ 8,600 cfs | That necessary to achieve duration target in Reach 2 |
| Reach 2 | ≥ 26,400 cfs | One day in wet years |
| | ≥ 22,700 cfs | Two weeks (i.e., 14 days) in wet years |
| | ≥ 18,600 cfs | Four weeks (i.e., 28 days) in wet years |

Flow Recommendations and FEIS

## *Moderately Wet*

If the April through July unregulated inflow into Flaming Gorge Reservoir remains above 1,751,000 AF the hydrological classification would be wet. However, the Yampa River flow volume forecast falls within the average (below median) classification. The Yampa River is necessary to meet wet and moderately wet targets. It is recommended to operate Flaming Gorge down one classification within the moderately wet hydrologic classification.

It is unlikely that the moderately wet classification targets will be met with the current Yampa River forecast in the average (below median) classification. However, the Record of Decision flexibility limits the decrease in hydrologic classification to one below the unregulated inflow volume into Flaming Gorge Reservoir.

The ROD spring flow objectives for moderately wet years are:

**Table 6 -- Moderately Wet 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 | ≥ 20,300 cfs | 1 day in moderately wet years |
| | ≥ 18,600 cfs | 2 weeks (i.e. 14 days) in moderately wet years |

Flow Recommendations and FEIS

## *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 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