STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
OROVILLE EMERGENCY RECOVERY – SPILLWAYS

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2018 Seasonal FCO Gate Closure Plan for Lake Oroville

April 16, 2018

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Introduction

During normal flood operations, Lake Oroville's Flood Control Outlet (FCO) spillway was damaged on February 7, 2017. Reacting to that, DWR elected to deviate from the 1970 U.S. Army Corps of Engineers (USACE) water control manual (WCM) for Lake Oroville. The WCM gives the Director of DWR authority to modify operation temporarily during emergency situations such as when dam safety is a concern. DWR coordinated this deviation with USACE, and USACE concurred. DWR reduced—and then halted—reservoir releases in the gated spillway. With continued reservoir inflow due to storm runoff, the reservoir pool level rose to elevation 901 ft. This led to the first-ever emergency spillway release. Flow down the unlined emergency spillway slope caused erosion and scour, raising concern about dam safety. Following the incident in February 2017, repairs were made to both the FCO spillway and emergency spillway.

In October 2017, a plan for operating the partially restored FCO spillway from November 2017 through April 2018 was developed to maintain dam safety and manage flood risk. The *Lake Oroville 2017-2018 Flood Control Season Operations Plan* (Operations Plan) was developed to address the interim FCO spillway flow limitations. The Operations Plan outlined operational strategies that limited the FCO spillway design release to 100,000 cubic feet per second (cfs). The Operations Plan ensured dam safety, provided downstream flood protection, and met the existing USACE flood control requirements set forth in the WCM. DWR also targeted lower lake elevations than required by the existing WCM.

This Seasonal FCO Gate Closure Plan (Plan) details the near-term operation plan for Lake Oroville including final FCO spillway gate operations for this season and with a preliminary look at anticipated operations and forecasted lake elevations through the end of November. This Plan incorporates actual and forecast snowpack information and technical analyses that will support the final FCO gate closure with the intent to maximize the 2018 construction season.

Primary Objectives

DWR, in order to manage the risks for public safety, developed two primary objectives governing this Plan for Lake Oroville and they are:

1. Lengthen the construction window as much as feasible to ensure recovered spillway flow capabilities are achieved prior to next winter
2. Begin FCO demolition at the earliest date for which risk of emergency spillway use has become negligible.

Strategy

In recognition and management of risks associated with hydrologic uncertainties such as significant late season precipitation events and the passage of an appropriate

volume of snowmelt prior to the final FCO gate closure, along with any unscheduled outages pertaining to the use of Hyatt Powerplant (Hyatt) and its appurtenances, this Plan must be adaptive and flexible to be successful. Real-time conditions create a dynamic environment and this Plan must accommodate these changing circumstances.

Upper Feather River Basin Hydrology

California hydrology varies widely by region with Northern California receiving the most precipitation. The highest monthly volume of precipitation occurs in the months of November through March. Conversely, the months of June to September produce almost zero precipitation volume. Runoff in the months of April, May, and June are primarily a function of snow accumulated through April 1. The hydrology not only varies by region and time of year, but it also varies widely from year to year as seen in Figures 1 and 2, which are discussed below in more detail.

Precipitation Variability

The Northern Sierra Precipitation 8-Station Index covers the major watersheds in the northern Sacramento Valley (Figure 1) and shows that water year 2016-2017 set a new record for total annual precipitation of 94.7 inches, compared to water year 1982-1983, which had been the wettest on record, with an annual total of 88.5 inches (Table 1).

Conversely, Figure 1 shows the 8-Station Index for water year 2017-2018, to date, has been tracking well below the 1966-2015 historical average. As of April 11, the cumulative precipitation for water year 2017-2018 is only about 37 inches compared to about 87 inches for the same period during the 2016-2017 water year.

Table 1: Comparison of Northern Sierra Precipitation 8-Station Index values.

Water Year	Cumulative Precipitation as of April 11 (Inches)	Water Year Total (Inches)	Percent of an Average Water Year
1983	79	88.5	171%
2017	90	94.7	183%
2018	37	37[1]	71%[1]

[1] Total inches and percent average as of April 11, 2018

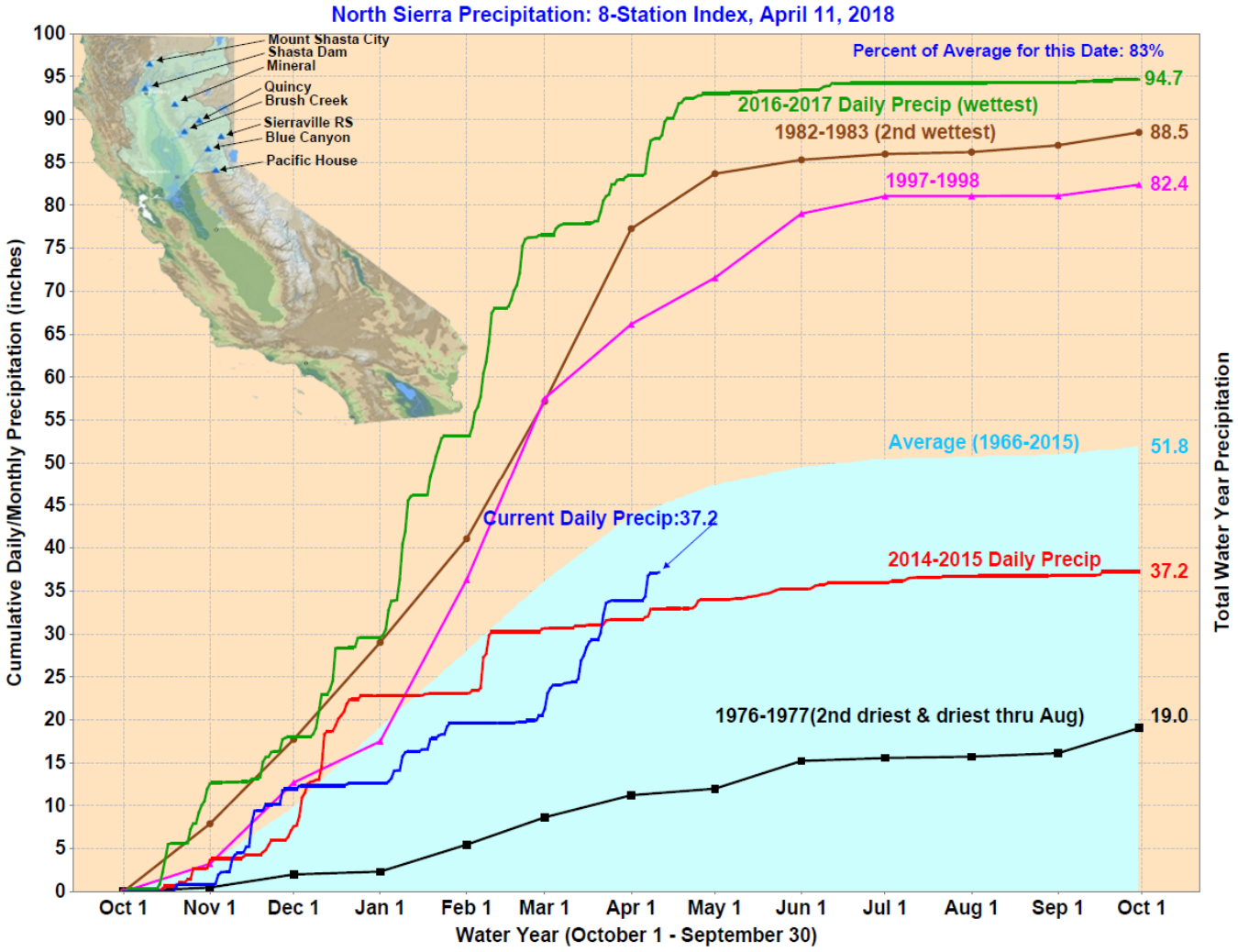

Figure 1: The 8-Station Index plot of precipitation shows that 2018 has been below the 1966-2015 historical average.

Snow Water Content Variability

The current snow water content is a stark contrast to water year 2016-2017, when snowpack in the northern Sierra was about 150% of the April 1 average for this same time period, as shown in Figure 2. The snow water content for 2016-2017 peaked around mid-April 2017 and the snowmelt for that water year lasted well into July.

As of April 10, 2018, the snow water content for the northern Sierra (Figure 2) was 34% of the April 1 average. The snow water content in the northern Sierra seems to have peaked around 50% of the April 1 average and has now started to decline.

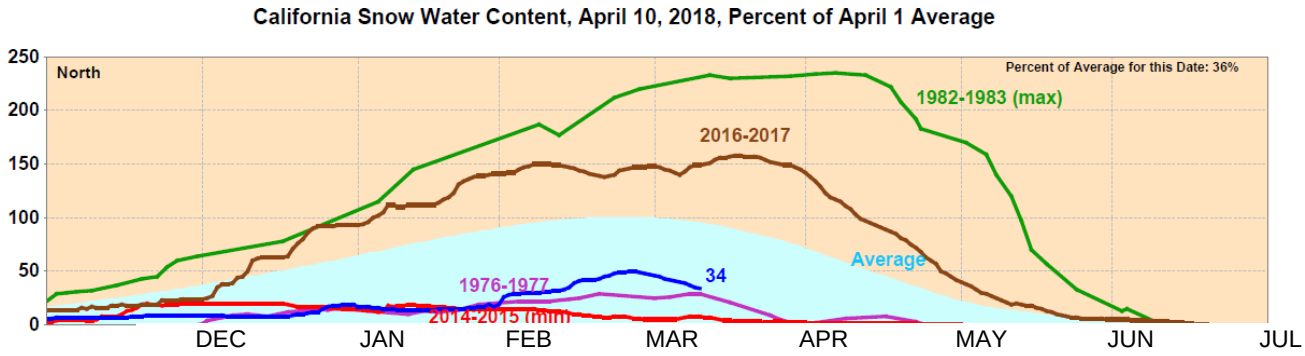

Figure 2: Below average snow water content to date for 2018 is close to other dry years like 1976-1977 and 2014-2015.

Reservoir Inflows

Lake Oroville inflows can be divided into three distinct seasons. During the months of November through March reservoir inflows are primarily a function of direct runoff from precipitation falling in those wettest months. Reservoir inflows in the months of April through June are primarily a function of snow melt runoff from the accumulated snow pack as of April 1 each year. Reservoir inflow in the months of July through October are primarily a function of releases from upstream reservoirs operated by Pacific Gas and Electric. Historically the direct runoff months produce the highest reservoir inflows followed by the snow melt months at a distant second. Inflows during the summer period are inconsequential.

Figure 3 illustrates actual inflows into Lake Oroville from April 15, 1980 to April 14, 2017. The highest peaks occurred in December through March from runoff due to atmospheric river storm events. From April to June, runoff from major precipitation events taper off and runoff becomes increasingly dominated by snowmelt. From June to November 1, historical inflows were significantly lower than the capacity of Hyatt.

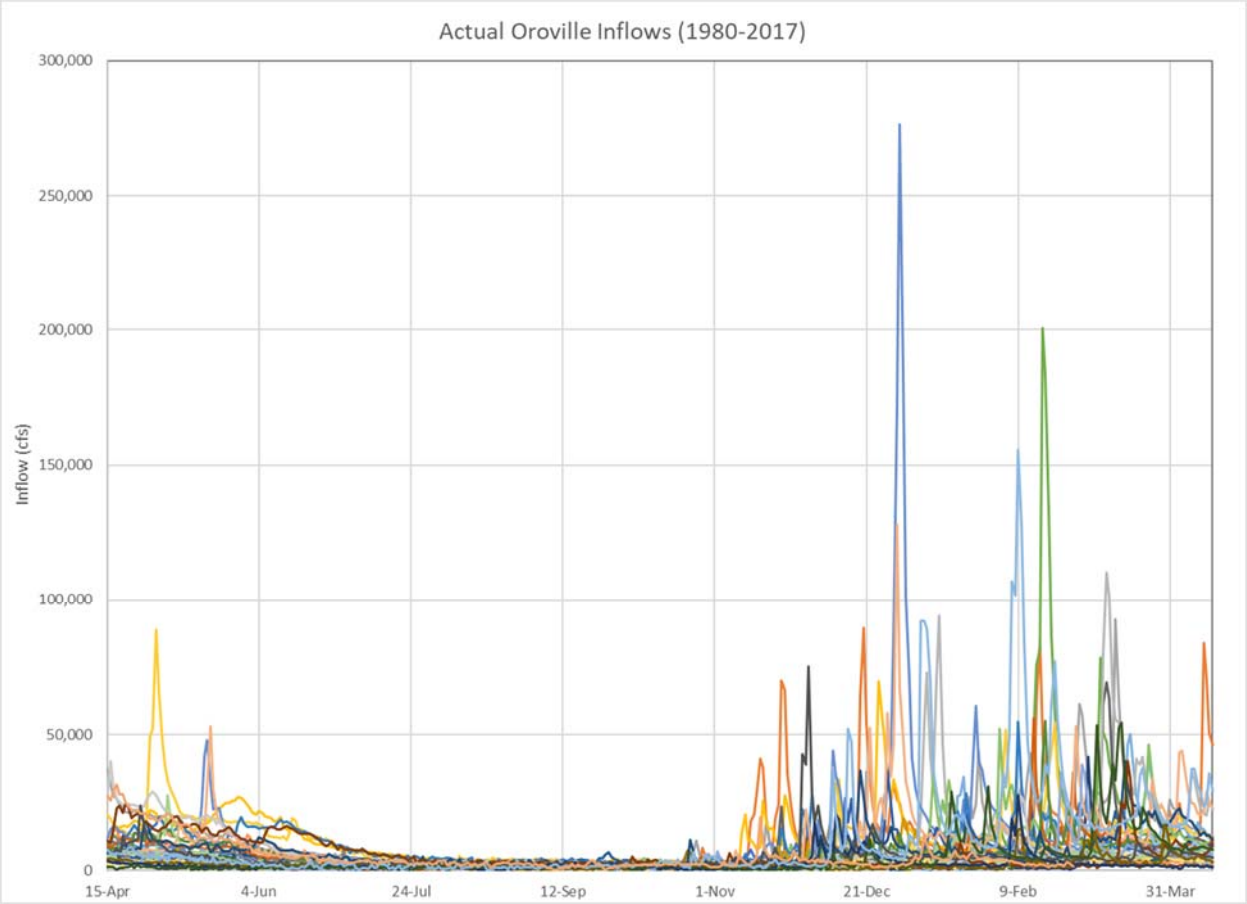

Figure 3: Annual distribution of historical daily inflows into Oroville shows high variably of winter precipitation and low variability in the summer.

Table 2 shows a comparison of the April to July runoff forecasts for 2017 and 2018, as of April 1 for each year, along with the average April to July runoff for the historical period 1966 to 2015. Runoff forecasts are unimpaired (full natural) flows which represent the natural water production of the river basin, unaltered by upstream diversion, storage, or export or import of water to or from other watersheds.[1] In the table, the 50% exceedance is the projected median runoff forecast for April to July (1,090 TAF) and it can be seen that 90% of the projected runoff forecasts will likely only exceed 800 TAF. Even under wetter assumptions as illustrated by the 10%

[1] From *B-120 Water Supply Forecast Update Summary (posted on 03/15/18 14:05)*, http://cdec.water.ca.gov/b120up.html

exceedance forecast the projected runoff of 1,340 TAF is well below the historical average (1,704 TAF).

Table 2: Comparison of April to July runoff forecasts.

Year	Apr – July Runoff Forecast (TAF)[1]	Percent of Average
2017	**2,790**	**164%**
2018 (90% exceedance)	**800**	**47%**
2018 (50% exceedance)	**1,090**	**64%**
2018 (10% exceedance)	**1,340**	**79%**
Historical Average[2]	**1,704**	**100%**

[1] April through July forecast of runoff as of April 1 for each year
[2] Historical average for 1966-2015 period

The National Weather Service (NWS) California-Nevada River Forecast Center (CNRFC) produces forecast ensembles (Figure 4) which overlay 59 years of historical events onto the current conditions in the basin and forecast the Lake Oroville inflows up to one year. The current conditions include snowpack conditions and soil moisture, on which forecasts of future precipitation, wind, and temperature are applied.

The NWS ensemble forecast predictions incorporate the following:

1. Days 1 to 3, NWS meteorologist forecasts incorporates current temperature, precipitation, freezing temperatures, and watershed conditions.

2. Days 3 to 15, NWS's Global Ensemble Forecast System weather model.

3. Day 15 and beyond, climatology (applying historical temperature and precipitation inputs).

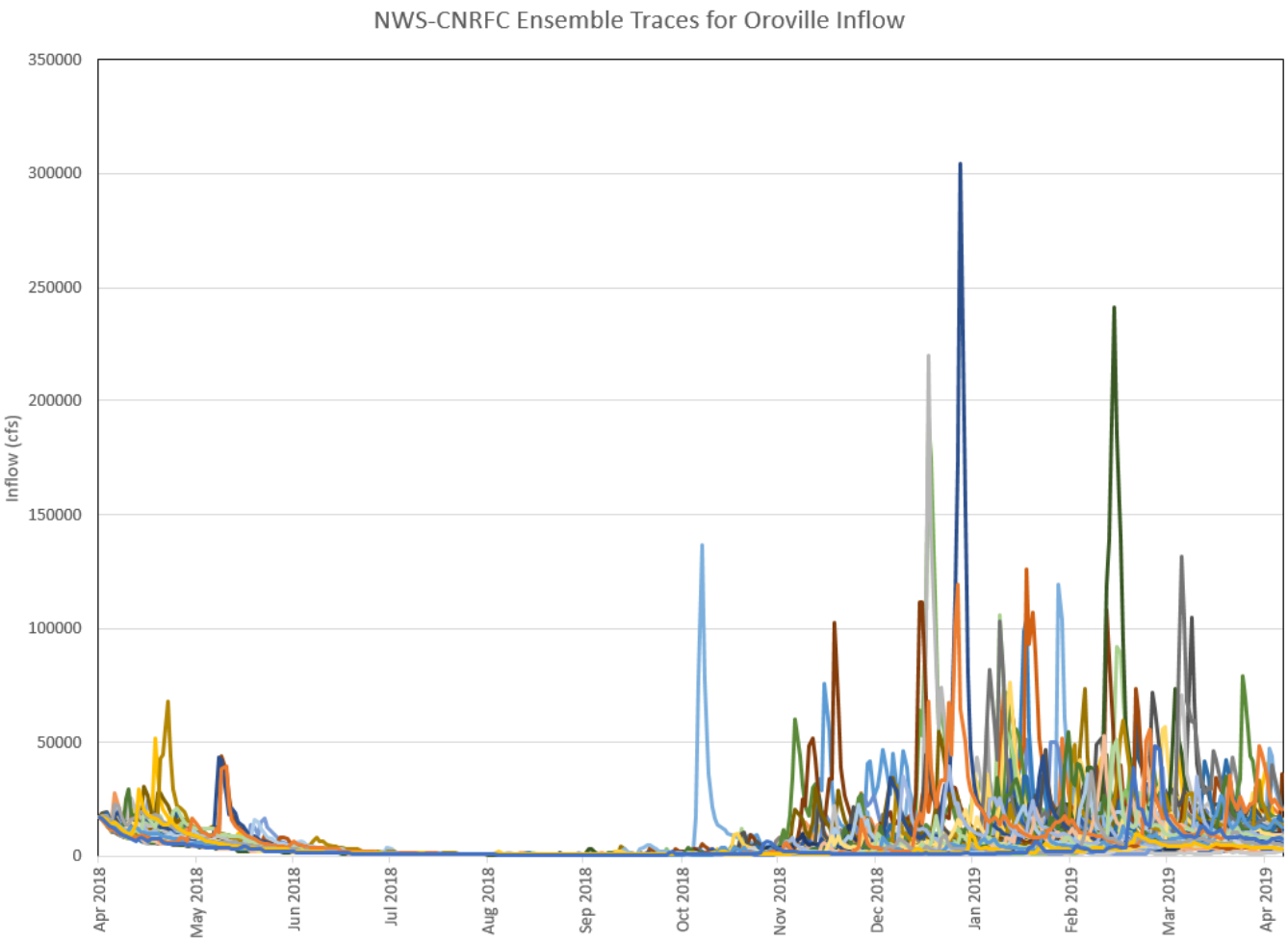

Figure 4: NWS-CNRFC ensemble traces of potential Oroville inflow from April 11, 2018 to April 11, 2019 indicate reducing inflows into summer, but potential for high inflow going into the winter.

The ensembles traces depicted in Figure 4 include actual conditions beginning on April 11, 2018 along with forecasted inflows to Lake Oroville through April 11, 2019. The forecast of inflows indicates reducing inflows into summer, but potential for high inflow starting early November and going into the winter. Similar to actual inflows shown in Figure 3, peak inflows occur from December through February with mainly lower flows occurring June through October with one notable exception[2].

[2] The so called “Columbus Day Storm” occurring in 1963 was considered a 250-year event for October.

Reservoir Storage

Reservoir inflows vary not only during the year, but from year to year, as well. This inflow variation translates directly to variances in water storage from year to year. As shown in Figure 5, during water year 2016-2017, storage in Lake Oroville significantly exceeded the storage in 2017-2018. Currently, storage is tracking about 695 thousand acre feet less than last year at this time. In addition, as noted previously, the below average snowpack will not provide the same refill potential during the April through July runoff period as it typically does.

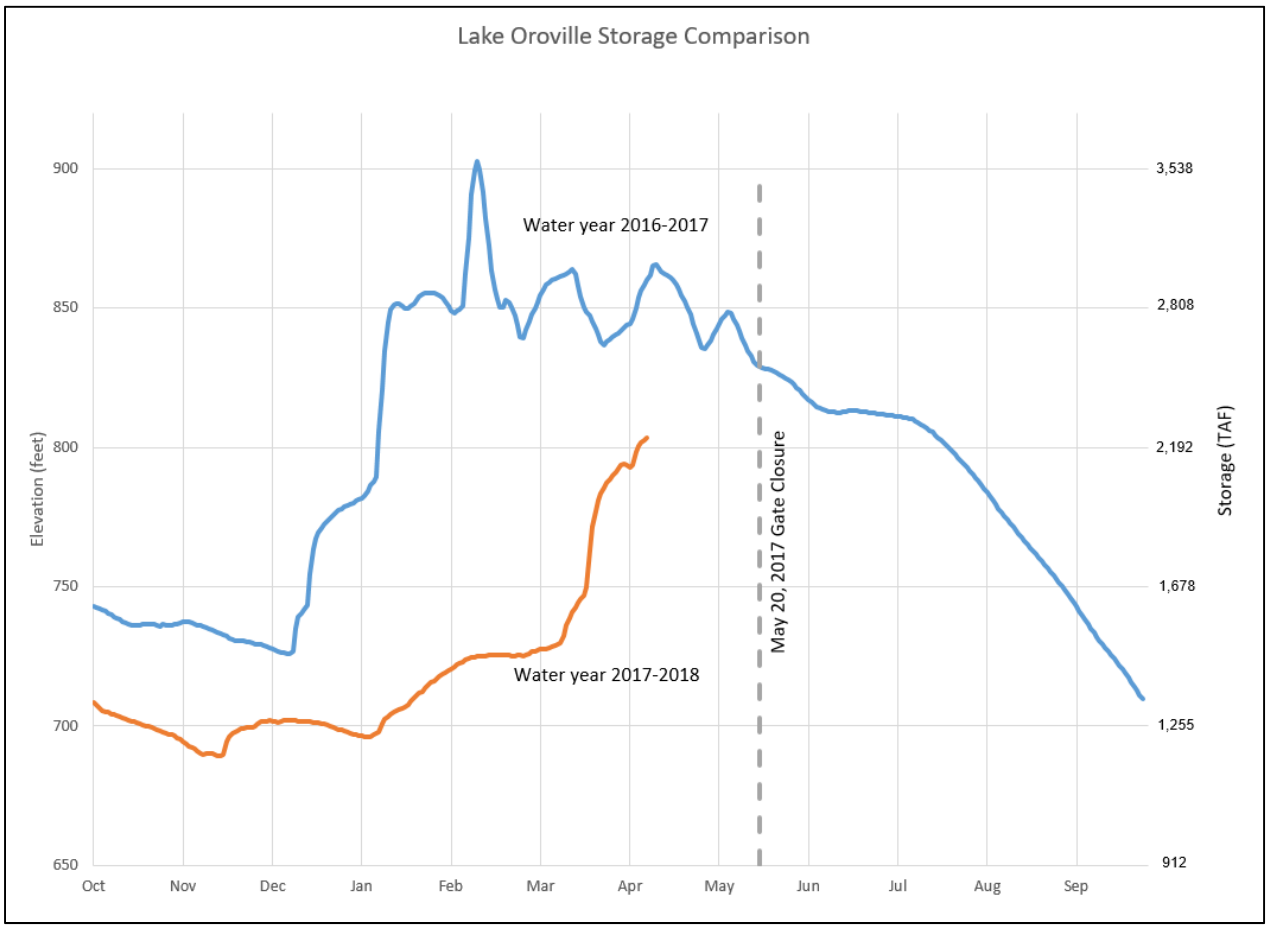

Figure 5: Lake Oroville water year 2016-2017 and 2017-2018 elevations.

Historical 2017 Operations

Since the February 2017 incident, the FCO spillway has been used three times with each cycle ranging from 11 to 29 days. The decision to use the FCO spillway was based upon projected inflow hydrology and storage levels and the stable condition of the FCO. The last cycle the FCO spillway gates operated was from May 10 – 19, 2017.

Demolition of the FCO spillway chute began on May 20, 2017 when the lake was at 835 feet. Outflow from the lake was released in such a manner to meet downstream needs with the final objective of reaching elevation of 700 feet by November 1. Figure 5 and Figure 6 both show the 2017 elevation drawdown of the lake to meet the November 1 target.

Historical 2018 Operations

Following November 2017, the lake elevation slowly increased as the winter season progressed, but at no time during the November 2017 to April 2018 period did the lake reach an outflow trigger elevation as outlined in the 2017-2018 Operations Plan (Figure 6).

For most of the winter, the below average precipitation, snowpack, and inflows resulted in releases to the Feather River that have been made to meet both minimum instream and Bay-Delta requirements while conserving storage for future releases to meet downstream needs. One exception was a significant increase in releases in early April to moderate elevation gains from peak inflows associated with a warm precipitation event occurring early in the month. This dramatic late winter hydrologic change complicated planning efforts as action was taken to avoid rapid elevation gain to elevation 830 feet and potential use of the FCO during the month of April. This action was successful and risk of reaching elevation 830 feet before late in the month has been abated. Since that early month precipitation event, the storage elevation gains have stabilized and the releases to the river are being ramped back down.

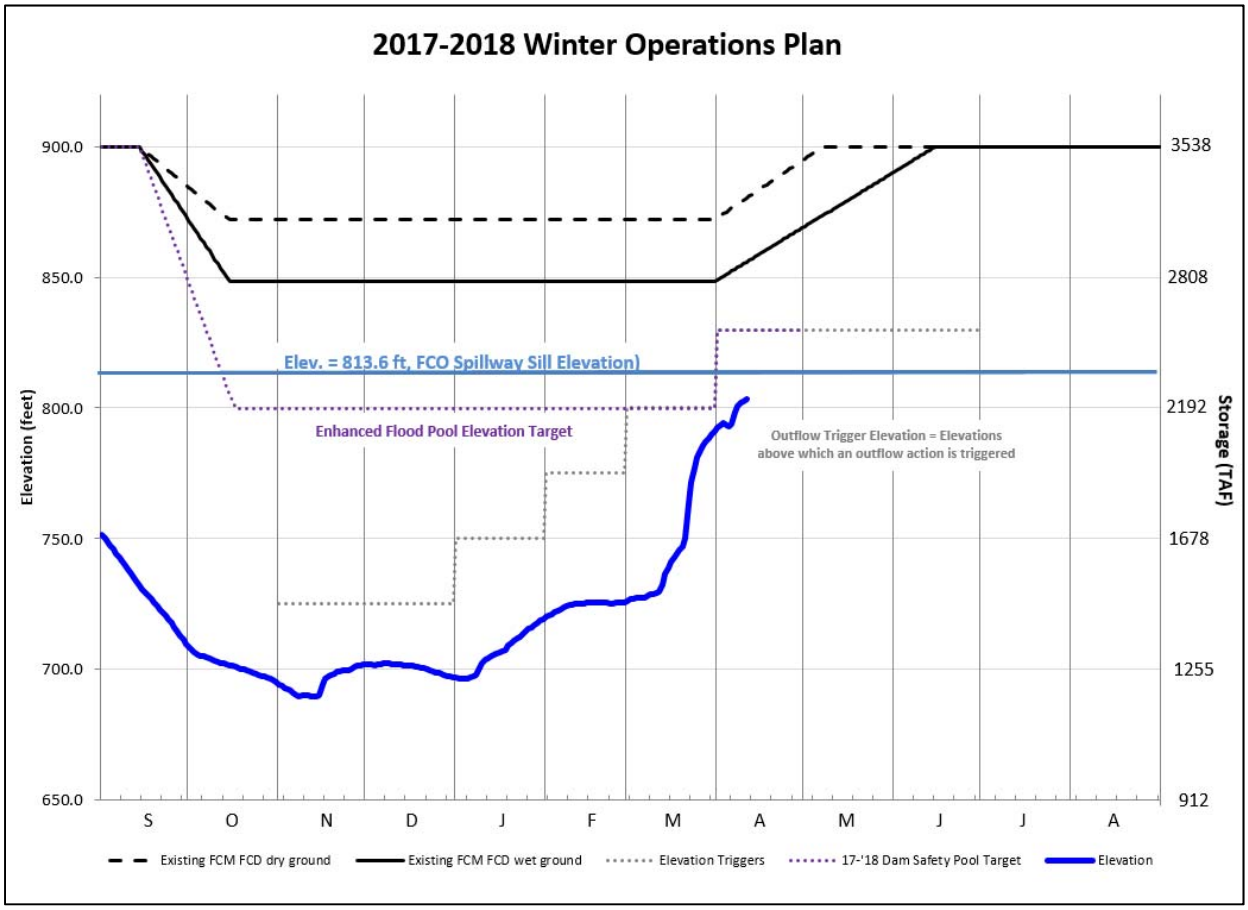

Figure 6: Lake Oroville elevation, beginning September 2017 through April 11, 2018, showing drawdown of lake to 700 feet by November 1, 2017 and the increase of storage at the end of the winter season.

Forecasted 2018 Operations

Using HEC-ResSim, DWR has performed analyses assessing near-term reservoir elevations using the ensemble inflow forecast provided by the CNRFC through the next thirty days. The latest analysis, (performed April 12, 2018) shown in Figure 7, indicates that the reservoir is likely to top out below elevation 830 feet by mid-May. There is still a potential for lake elevations to rise to nearly 850 feet although the probability appears low.

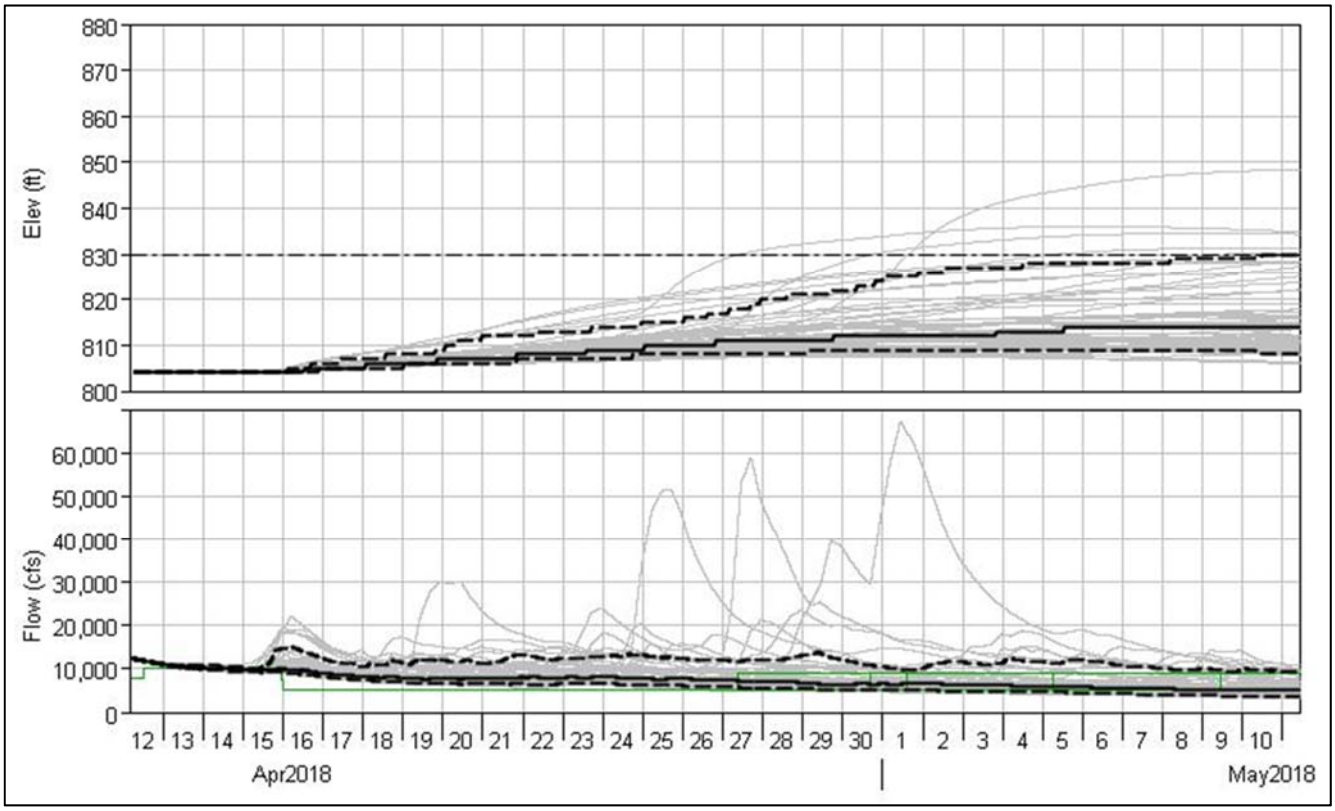

Figure 7: Lake Oroville projections of elevations and releases through May 10, 2018 following May 8, 2018 gate closure.

Figure 8 shows the variance of maximum pool elevation by month from the HEC-ResSim analysis. This figure indicates that May has the potential for higher maximum lake elevations compared to April.

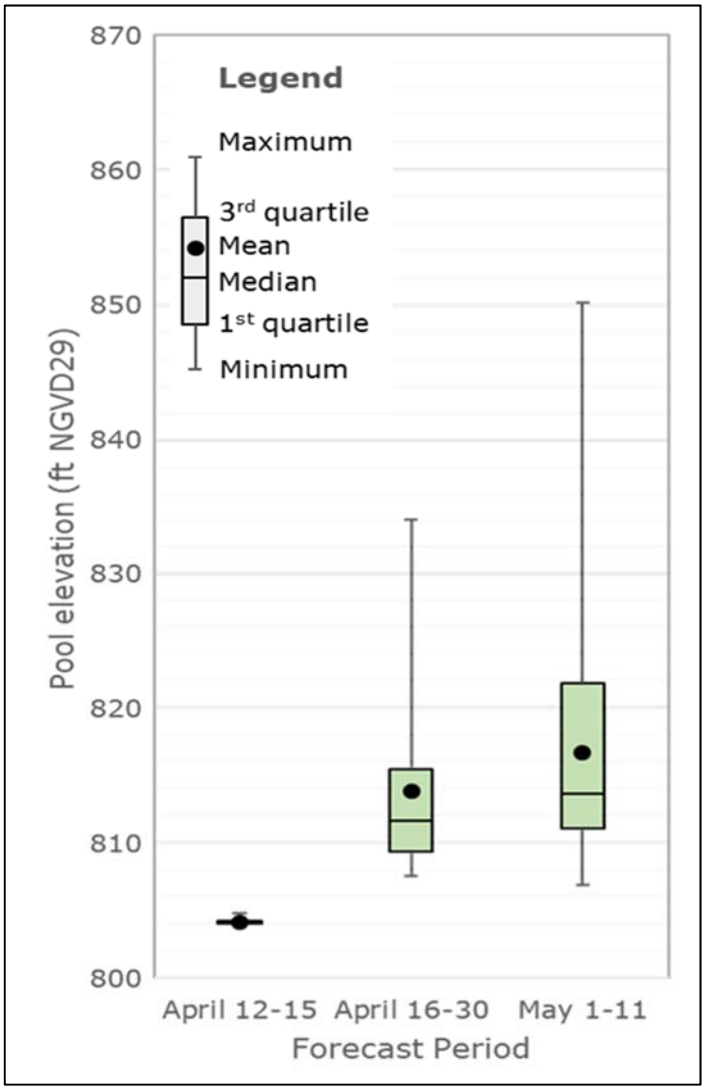

Figure 8: Variance of maximum pool elevation by month from analysis of ensemble forecast.

Table 3 shows the maximum pool elevation and release percentiles by forecast period based on the analysis. The table shows a simulated gate closure on May 8, 2018 combined with inflows from the ensemble forecast may result in a maximum pool elevation of only 848 feet and maximum release of only 10,000 cfs. The table also shows that 90% of the simulations had a maximum pool elevation of 830 feet or less with a maximum release of 10,000 cfs or less.

Table 3. Ensemble maximum pool elevation and release percentiles by forecast period

Statistic[1]	Maximum pool elevation (ft) for forecast period			Maximum release (cfs) for forecast period		
	April 12 - 15	April 16 - 30	May 1 - 11	April 12 - 15	April 16 - 30	May 1 - 11
Maximum	805	834	848	10,000	9,000	9,000
10% exceedence	804	824	830	10,000	7,500	5,000
20% exceedence	804	818	825	10,000	7,500	5,000
30% exceedence	804	815	818	10,000	7,500	5,000
40% exceedence	804	813	815	10,000	7,500	5,000
50% exceedence	804	812	814	10,000	7,500	5,000
60% exceedence	804	811	812	10,000	7,500	5,000
70% exceedence	804	810	811	10,000	7,500	5,000
80% exceedence	804	809	810	10,000	7,500	5,000
90% exceedence	804	808	809	10,000	7,500	5,000
Minimum	804	807	807	10,000	7,500	5,000

[1] For example, 10% exceedence means the maximum pool elevation was 804 ft or greater in 10% of the simulations (approximately 6 out of 59 ensemble members) during the period of April 12 through April 15.

Each spring and fall there is a Hyatt penstock outage for routine maintenance. During the spring 2018 outage, the April 16 through May 11 Hyatt capacity will be at 5,000 cfs. However, in the event additional outflow capacity is needed, the River Valve Outlet System (RVOS) can be put into service and provide an additional 4,000 cfs of capacity. Beginning May 11, Hyatt is expected to have five units available with a capacity of about 13,000 cfs. The ensemble runs have taken these outage assumptions into account.

Construction Considerations

As discussed previously, the HEC-ResSim analyses have indicated there is a potential for lake elevations to rise to nearly 850 feet. Although the probability of this occurring appears small (1 in 59 or 2%), extensive coordination with Kiewit has led to the conclusion that water behind the FCO gates would not pose a significant impact on safety or construction schedules. DWR has prepared Technical Memorandum (TM) SRT-FCO-DOC-12 confirming the minimal risks to construction activities and public safety should the lake reach these elevations, along with applicable remediation measures, and included as Attachment A to this Plan. Topics discussed in the TM

attachment include stability of the FCO headworks structure, construction sequencing, and seepage and groundwater conditions.

Seasonal FCO Gate Closure Date

In preparation for the spillway repairs, DWR plans to establish a seasonal closure date for the FCO gated spillway of May 8, 2018. Beyond this date the availability of Hyatt and the RVOS will ensure that reservoir inflows produced by late season precipitation and snowmelt can be adequately released.

The May 8 date is twelve days earlier than the final seasonal gate closure date of last year. The earlier closure date for this year is justified given this year's subpar snowpack is projected to be largely exhausted by early May.

An outflow trigger elevation of 830 feet will be employed for the months of May and June to trigger increased Hyatt releases of up to 10,000 cfs. This outflow action should be achievable without undue risk being placed on the Hyatt generating units. As shown previously in Figure 5, an FCO gate seasonal closure on May 8 with a potential lake elevation near 830 feet would be comparable to the conditions of 2017. As experience has shown from 2017 operations, a lake elevation around 830 feet at the time of the FCO gate closure did not have significant impacts on safety or construction. A lake elevation of 830 feet can also be drawn down to the FCO sill elevation of 813 feet in a short period (approximately two weeks), further facilitating safety and construction needs if necessary.

Although it is unlikely that elevation 830 feet will be reached this season, this elevation is also well below the elevation for which the reservoir can be easily managed back down to a reasonably low level by the fall. Under some scenarios as a result of significant but rare late season precipitation events the reservoir elevation may increase above elevation 830 feet. However, this will not pose any risk to reservoir management this spring nor will it pose any challenges to the draw down to reasonably low levels next fall.

Beginning no later than July 1, Lake Oroville storage will be drafted to meet local water deliveries, flow and salinity obligations in the Sacramento-San Joaquin Delta, and deliveries to State Water Project water supply contractors south of the Delta. Releases will be made on a pattern that meets these beneficial needs and achieves an end of September storage elevation of 710 feet. This target will be completely within the control of the Project operators considering additional reservoir inflows are negligible during the summer period. Into the fall, it is anticipated that additional drafting of the lake will occur and the lake elevation will be below 700 feet by the construction milestone of November 1, 2018.

This low elevation will also provide a desirable buffer of vacant storage should the completion of the FCO spillway be delayed coupled with any unusually early start to the 2018-2019 rainy season.

As stated earlier, Hyatt capacity is sufficient to manage expected inflows into the fall. However, it is important to look at possible draw down forecasts for the lake elevation to ensure reasonably low lake elevations are achieved prior to next winter.

DWR will continue to provide bi-weekly reports until the spillways construction is completed. In the June 1 bi-weekly report, DWR will provide the operation forecast which will guide the lake drawdown to the September 30, 2018 target of 710 feet, similar to the reports that were submitted during the summer in 2017.

Contingency

The River Valve Outlet System (RVOS) will be available to pass flow at a rate of at least 4,000 cfs as a contingency in the event additional outflow capabilities are required during the 2018 FCO construction season. The RVOS, will only be used as a contingency in the event of an unexpected loss of capacity at Hyatt or for temperature management in the late summer into early fall. Prudent management of the cold water pool is critical for the survival of fish species later in the summer and fall and is therefore essential that this cold water pool be conserved earlier in the year.

Conclusion

Peak accumulation of snowpack on April 1, 2018 was one-third the accumulated snowpack the year prior and is expected to be largely exhausted by early May. In preparation for the spillway repairs in a manner that is consistent with the objectives of this Plan, DWR plans to establish a seasonal FCO gate closure date of May 8, 2018. Beyond this date the availability of Hyatt and the RVOS will ensure that reservoir inflows produced by late season precipitation and snowmelt can be adequately released and a reasonably low reservoir elevation will be achieved by the fall.

ATTACHMENT A – Technical Memorandum SRT-FCO-DOC-12 (CEII)