

## Lake Oroville Spillways Emergency Recovery

### Board of Consultants Memorandum No. 6 – May 16, 2017

Prepared by the California Department of Water Resources

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## Summary & Response

### Question 1

Question 1 relates to the most recent geologic exploration that was completed to ensure an adequate understanding of the conditions associated with the geology in and around the spillways. There are a variety of tools that DWR used in understanding the geologic conditions which are outlined in the BOC memorandum. The BOC also describes the piezometer data that was recently collected. This instrumentation was recently placed to get a better understanding of the pressures within the foundation beneath the spillways.

### Question 2

Self-Explanatory

### Question 3

Question 3 relates to the review of the plans and specifications by the BOC. The BOC is recommending that DWR consider various designs to collect water that will be adjacent to the FCO Spillway.

### Question 4

DWR discussed the various design and construction deficiencies associated with the original spillway design that were outlined by the Forensic Team. The purpose of this discussion was to ensure the new design would not repeat any problems that could have been a factor of the failure of the chute or erosion of the rock downstream of the emergency spillway. The BOC concludes that the new design will alleviate the issues outlined by the Forensic Team.

### Question 5

Question 5 relates to a Potential Failure Mode Analysis (PFMA). As part of any new design, FERC requires a PFMA. The PFMA process lays out what if scenarios including every conceivable issue of the physical conditions then ensures each issue has been mitigated. The primary purpose of this PFMA was to evaluate all possible ways any feature of the spillways could fail that would result in some level of consequences to the project and or the downstream reaches. A team of experts worked together to understand all potential weaknesses that may exist so that actions or re-designs could take place to reduce or eliminate that weakness. The BOC reviewed the PFMA for the Oroville Spillways and concluded the study was comprehensive and will ensure the operations and construction will be safe based on the study.



**Question 6**

Question 6 relates to an independent study conducted by the US Army Corps of Engineers (Corps) to ensure the reservoir could be operated safely during the summer months since the radial gates would need to be closed to allow construction. The BOC concludes that the independent study by the Corps supports DWR's conclusions which emphasizes that the operation of the reservoir through the summer and fall as planned will result in a safe condition.

**Question 7**

Question 7 relates to the same subject of question 6 and is in regards to the supporting engineering used by DWR to evaluate the operation of the gates during the summer months.

**Questions 8 and 9**

Self-Explanatory



# OROVILLE EMERGENCY RECOVERY – SPILLWAYS

## Board of Consultants Memorandum

DATE: MAY 16, 2017

TO: Mr. Ted Craddock, Project Manager  
Oroville Emergency Recovery – Spillways  
California Department of Water Resources

FROM: Independent Board of Consultants for  
Oroville Emergency Recovery – Spillways

SUBJECT: Memorandum No. 6

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### INTRODUCTION

On May 15 and 16, 2017, the Independent Board of Consultants (BOC) met at offices of the California State Department of Water Resources (DWR) for presentations on the status of geologic explorations, various new or revised technical memoranda, details of design revisions to the drawings and specifications for Contract 2, and discussions on various engineering documents related to the Oroville Spillway Recovery. The meeting ended on May 16 with a reading of the BOC's draft report at 4:30 pm. An agenda for the meeting is attached. All current BOC members were present; we are pleased to welcome new BOC member John Egbert. The BOC met with representatives of DWR, DSOD, FERC, and industry consultants that are working on the Oroville Spillway Recovery project; the attendees at the meeting are shown on the attached attendance record.

### QUESTIONS FOR THE BOC

1. Does the BOC have any recommendations or comments on the geologic explorations?

#### *Response*

The BOC received a status update of the on-going field exploration program that includes mapping, drilling, surface geophysics, and instrumentation. As of this

meeting, 94 of ~100 exploratory borings, and 33 of 39 concrete cores in the FCO Upper Spillway Chute, have been completed. Seven piezometers (5 vibrating wire and 2 open standpipe) have been installed. An optical or acoustic televiewer was used to image all borings.

The characterization of results from the geophysical seismic lines is ongoing. It should be mentioned that many lines have been extended or moved from their initial planned locations, or their lengths extended to adapt the exploration to the new geological information that has been obtained. Due to the seismic “noise” the lines cannot be run while the FCO Spillway is flowing (which has been flowing for most of the last two weeks) or when construction machinery or traffic is nearby. An important design change that has come about, based partially on seismic line results, but also on borehole exploration data, is that the secant cutoff wall for the Emergency Spillway has been moved about 350 feet further downstream and is now located about 600 feet downstream of the Spillway. This change was in order to place the cutoff wall in an area where better quality rock is closer to the surface. The BOC awaits a more complete geologic characterization of the new cutoff wall alignment.

Several of the 8-inch-diameter concrete cores obtained in the upper FCO Spillway Chute were shown to the BOC, as well as video imagery of conditions in some of the shallow core holes; these borings showed that bond conditions were better than expected at the concrete and foundation interface in the upper Chute for much of the upper FCO Chute floor that will remain in place during the 2017-2018 flow season. Areas with poor bonding, such as the far downstream end (Stations greater than 23+00) or in the area where either more clay or highly weathered rock existed [REDACTED] will either be removed or receive mitigation repairs. In almost every case, the Chute concrete thickness was greater than 2.5 feet. Much of this information has been summarized in a Technical Memorandum (TM SRT-FCO-GO-03, “titled, *“Spillway Chute – Phase 1 Exploration Drilling Observations”*”) for the Phase 1 activities in April 2017 and another TM (TM SRT-FCO-GO-04) is in progress for

subsequent and current activities. The BOC recommends that all available borehole records (in whatever state they currently exist) be posted so they can be reviewed by the BOC.

The BOC was given an update on data obtained by piezometers (vibrating wire) that were installed in borings outside of the FCO Spillway. Of the eight piezometers installed, two showed some response during the short time that FCO Spillway flow occurred (from April 14 to May 1, 2017). One piezometer (B-39) showed erratic response and its data is being re-evaluated. It may be useful to assess the hydrologic conditions that have contributed to, or restricted flows to the piezometers.

The BOC was given an update on data obtained from piezometers that were installed beneath the existing upper FCO Spillway Chute. Piezometers were installed at 4 locations, and at two of these borings, two vibrating-wire piezometers were installed, one located near the top of the amphibolite, near the concrete interface, and the other piezometer is located deeper within the rock with both instruments hydraulically separated by concrete backfill (thus, 6 piezometers at 4 boring locations). The data from these instruments will be obtained remotely once the FCO Spillway flow is stopped. The BOC awaits the results of what water pressures exist at these depths after Spillway flows have occurred.

**2. Does the BOC have any recommendations or comments on the technical memoranda?**

*Response*

Members of the BOC have reviewed and provided comments on a number of draft technical Memoranda in its previous reports. The seismic design criteria were included in the following TMs:

- *Geologic/Geotechnical Design Criteria Memorandum (SRT-ORO-GE-01)*
- *Structural Design Criteria (SRT-ORO-ST-01)*
- *Recommended Earthquake Ground Motions Estimates (SRT-ORO-ST-03)*

- *Revised Earthquake Ground Motion Estimates (SRT-ORO-ST-12)*
- *Acceleration Time Histories for Oroville FCO Structure Non-Linear Stability Analysis (SRT-ORO-ST-13)*

The above TMs have now been issued as final documents. The BOC provided specific comments on these documents and concurred with adopted criteria. However, there are minor differences in seismic design criteria between documents that need to be reviewed and explained or reconciled. As an example, the Structural Design Criteria TM indicates that “Interim Repairs” should be designed based on 2,475-year return period ground motions based on Probabilistic Seismic Hazard Analyses (PSHA). This criterion, as recommended in the ground motion estimates in SRT-ORO-ST-03, would indicate a horizontal peak ground acceleration (PGA) at bedrock of 0.26 g. The seismic design criteria listed in the Geologic/Geotechnical Design Criteria Memorandum (SRT-ORO-GE-01) indicate that the design of short-term “Interim” structures is based on an Operating Basis Earthquake (OBE) with a return period of 144 years, with a PGA of 0.08 g. For the permanent “Non-Dam Safety-Related” structures the specified ground motions are based on a 475-year return period with a PGA of 0.12 g. The differences between the adopted design criteria need to be explained and/or reconciled.

The BOC would like to review the revision to the structural criteria TM, *SRT-ORO-ST-01 Structural Design Criteria*, before providing its final comments now that all structural elements in the design are defined.

The BOC has reviewed the TM entitled *SRT-FCO-CS-03 Flood Control Outlet (FCO) Spillway Alternative Foundation Construction Methodology* and concurs that this is a suitable option for treatment of the lowest part of the erosion channel by use of flowable concrete to encapsulate the large loose rock located in the bottom. This was presented as an optional method, which the Contractor can choose to use for startup of his RCC placement.

The BOC considers that the TM's *SRT-FCO-DOC-06 Revised FCO Upper Chute Construction Sequence and Phasing* and *SRT-FCO-GE-03 Independent Expert Peer Review FCO Left Slope Stabilization* have been reviewed and discussed during past meetings and has no further comment in their regard.

**3. Does the BOC have any recommendations or comments on the plans and specifications?**

*Response*

The BOC members have had a limited amount of time to fully review revised specifications and drawings but an initial perusal of the plan set indicates that the design has been fleshed out to suit the foundation conditions throughout the full length of the Chute, and design details have been developed to satisfy all loadings and requirements. The BOC is of the opinion that the drawings and specifications are ready for final review.

A presentation was made of the design changes that have been incorporated in the revised drawing set. The major issues that required revision of the design and drawings included an increase in the height of the training walls to accommodate a revised hydraulic profile of the maximum FCO Spillway discharge and a revision of the location of the secant wall downstream cutoff to better fit the existing geology. The BOC commends the Design Team's attention to calling for rigorous remedial treatment of spalls and defects in the Chute surface in the portion of the existing upper Chute which will remain in service until 2018.

A prior recommendation in BOC Report 5, suggested that consideration be given to modifying the Spillway under-drainage system to use an open ditch for collection of water from the transverse Chute drains. Such a ditch would parallel the training walls on either side and would also serve to pick up precipitation falling on the rock slope of the excavation cut. The Design Team reported that they questioned the practicality of providing a ditch of reasonable size that could handle the rainfall runoff from an extreme event. Concern over the velocities in

the ditch channel, which might occur in the steep area of the Chute, could require energy dissipation. Therefore, the Design Team preferred to retain the collection pipe system for both under-drainage and the precipitation runoff as shown on the drawing set. The BOC agrees that the drainage system as currently designed will function well and corrects the deficiencies of the existing Chute drainage system.

The BOC would, however, urge reconsideration of the open ditch drain system because of the advantages that a simpler open ditch design offers. It will be easier and quicker to construct. The outflow from individual cross-drains will facilitate monitoring of flow and maintenance and cleaning of the drains. These advantages, in the opinion of the BOC, outweigh the possible increased slope excavation which may be needed to provide room for the ditch. Calculations indicate a 4-foot-diameter half-round concrete precast channel section would have the capacity required and maximum velocities at the steepest slope of the ditch would be approximately 17 feet per second, well within the acceptable range to not require any special treatment.

The BOC is pleased to see that the RCC “shoulders” have been eliminated in the RCC Chute foundation section and the same general type of cantilevered training wall layout will be used throughout the entire length of the Spillway Chute. The revision also provides room for the open ditch drainage channels.

We were informed that the secant wall design was being modified to eliminate every third secant pile but no details of the layout were presented. This effectively creates independent wall elements that are 10 feet long and are separated from the next element by a 1-ft gap to allow for drainage. The BOC understands that a grade beam will tie the elements of the secant piles together as a stable wall capable of withstanding head cutting erosion. The BOC looks forward to reviewing the overall RCC blanket and wall design as well as the geologic characterization of the new secant wall alignment.



**4. Does the BOC have any recommendations or comments on the Forensic Team briefing?**

*Response*

The Forensic Team has cited a list of 24 design and construction deficiencies they identify as possible factors in the failure of the FCO Spillway Chute. The root cause of the initiation of the destructive damage has not been specifically identified at this time, but most certainly lies with one or more of these factors in combination. In the preparation of the redesigned Chute for the restoration of the FCO Spillway, the DWR Design Team has been cognizant of providing remedial measures and safeguards against all cited factors in their development of the replacement design. The BOC is confident that the design of the Spillway Chute that has been issued for construction meets the current standards of practice and provides a conservative solution to address all original design deficiencies.

Four concerns with the Emergency Spillway were also cited by the Forensic Team as Safety of Dams deficiencies. The DWR Design team has designed remedial measures to address each of these concerns and the BOC believes if these improvements are made on the Emergency Spillway, it can safely meet the criteria under the Interim Operational Period.

**5. Does the BOC have any recommendations or comments on the Supplemental PFMA briefing?**

*Response*

The BOC was presented with a summary briefing of the results of a Potential Failure Modes Analyses (PFMA) workshop that was completed on May 2-4, 2017. The workshop was attended by members of the Design Team, FERC, DSOD, DWR's Dam Safety and Operations staff, and a representative from Contractor, Kiewit. The workshop was facilitated by a designated Facilitator, and followed the format specified in FERC's guidelines. The workshop participants attempted to identify potential failure modes (PFMs) that could result in uncontrolled release of the reservoir water. Twenty-two PFMs were identified in the process, and were categorized as defined in FERC's PFMA guidelines. [REDACTED]

[REDACTED]

The BOC understands that this PFMA workshop was performed in accordance with FERC's Chapter 14 guidelines that require a "Supplementary" PFMA workshop be conducted after failure of a structure or prior to major modification or remedial work on a structure. The BOC believes that this PFMA approach provides a valuable tool to address credible potential failure scenarios that need to be explored and mitigated during the design process.

In addition to the formally developed PFMs, important "Other Findings" from the workshop indicated the need for a long-term solution; the potential significant impact of construction delays; the reliability of the Hyatt Power House for reservoir releases; and a proper documentation of DWR's decision-making process for reservoir operations. The BOC concurs with these findings.

The BOC understands that a draft report summarizing the results of the workshop is currently being prepared by the Project Team.

**6. Does the BOC have any recommendations or comments on the USACE SQRA?**

*Response*

A presentation by US Army Corps of Engineers personnel on their Semi Quantitative Risk Assessment evaluated the following risks associated with: 1) closing the FCO flows prior to June 1, 2017; 2) the reservoir pool elevation on

November 1 resulting from a closing of FCO on June 1, 2017; 3) operating the FCO, in its current condition (up to 100k cfs); and 4) operating the Emergency Spillway in its current condition (up to 110k cfs). The study indicates there is a low risk of the reservoir exceeding elevation 865-ft (FCO gate elevation) or 901-ft (Emergency Spillway crest), prior to June 1. The study analyzed several PFMs: potential failure of the existing FCO Chute slab (within 1,000 feet of the gated structure) and breach of the gated structure; potential failure of the Emergency Spillway monolith 19 by headward erosion through the current protection (placed during the last 2 months), as well as headward erosion into monolith 3. The study concluded that closing the FCO anytime in May presents low risk. Failure of either Emergency Spillway monoliths was deemed very unlikely. The BOC feels this study was comprehensive and effectively integrated geologic, hydrologic, operations, and risk. Further, this study emphasizes that the planned project approach to operations and construction will be performed in a safe manner.

**7. Does the BOC have any recommendations or comments on the Reservoir Pool Elevation - Frequency Curves for Long-Term RA?**

*Response*

The BOC followed with interest the presentations on the development of the data and tools, which are being used for assessing the hydrologic risk during the current FCO shutdown and in the coming winter flood season. These tools provide the means to quickly relate inflow, reservoir level and outflow by the FCO and/or powerhouse and obtain predictions of both near and long term projections. This capability is invaluable for use in reservoir operation and operation of the FCO Spillway particularly during the construction and the interim period of operation.

**8. Does the BOC have any recommendations or comments on the contract and construction status?**

*Response*

The BOC requests a copy for each member of:

- Bid Schedule
- Summary of Work

The BOC appreciates the Contract and Construction Status review, and requests that the review continue and that future status reports contain the following:

- Submittal Register
- RFI's
- Memorandum Directives and Change Orders
- Claims/Disputes
- Serial Letters and Contractor Letters

The BOC is primarily interested in comments to the above, which may have an impact to the schedule and/or which may result in a design change.

The BOC requests that presentation of the Three Week Roll Up Schedule and the Plan View photo continue.

**9. Does the BOC have any other recommendations or comments for the Design Team?**

*Response*

The BOC has no additional recommendations or comments for the Design Team.

**BOC RECOMMENDATIONS SUMMARY**

M6-1            The BOC recommends that geological exploration data (i.e., borehole, geophysical, mapping, groundwater level, slope stability, photography, drone videography, etc.) be made electronically available so they can be reviewed by the BOC in real time; that is, in whatever state they currently exist. As discussed, during the question and answer session after the BOC report presentation, on this project we do not have the luxury to wait on preparation of a

formal DWR report before exploration records are made available, otherwise design will be completed and construction will have begun prior to reports and data being available. The BOC recommends that field records be made available as soon as feasible after the data is collected.

- M6-2 The BOC recommends that a more complete geologic characterization of the new cutoff wall alignment be performed. All that has been presented to date are two seismic geophysical profiles.
- M6-3 The BOC would like an assessment of groundwater hydrologic conditions that contribute to, or restrict, flow to piezometers that are located outside of the FCO Spillway Chute.
- M6-4 The BOC would like a presentation on the water pressures recorded in the piezometers under the Chute after Spillway flow events. Six piezometers were installed underneath the upper Chute FCO slab prior to commencement of flows at the beginning of May.
- M6-5 The BOC recommends that differences in seismic design criteria between as currently presented in the structural and geotechnical TMs be explained and, or reconciled.
- M6-6 The BOC has done a preliminary review of the revised Contract 2 drawing set and agrees with the revisions that were made to the Spillway Chute design.
- M6-7 While the BOC agrees the Chute under-drainage system using collector pipes as presently designed is fully functional and corrects the inadequacies of the existing Chute drain system, it is suggested that changing the collection means to an open ditch design offers significant advantages.
- M6-8 The BOC looks forward to reviewing the layout of the secant cut-off wall for the Emergency Spillway.

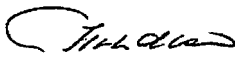
- M6-9            The BOC concurs that the DWR's design for the restored FCO Spillway has adequately addressed all the deficiencies identified by the Forensic Team in their evaluation of the existing Chute failure.
- M6-10           The BOC notes that the battery of hydrologic data and curves that have been developed provide an excellent means for projections of inflow to the reservoir and planned operation of FCO and powerhouse releases.

Based on a conference call after the meeting between the DWR Liaison member and the BOC, it was decided that DWR will provide the BOC with more detailed information prior to future BOC meetings that will be covered in the meetings. This will allow BOC members to begin their review before the actual day of the meeting. The BOC believes this will allow a more thorough review and better-written BOC Report.

Respectfully submitted,



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