**Lake Oroville Spillways Emergency Recovery**

# Board of Consultants Memorandum No. 14 – December 1, 2017

Prepared by the Department of Water Resources

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## Summary & Response

**Question 1**

Question 1 relates to the recognition by the Board of Consultants (BOC) regarding the completion of work and meeting the November 1, 2017 deadline. The BOC concludes that the Flood Control Outlet is ready for service as planned.

The BOC also comments on the on-going work at the emergency spillway. The BOC also addresses potential shortage of fly ash. Fly ash is one component of the roller compacted concrete (RCC). RCC will be used to construct revisions to the emergency spillway.

**Question 2**

Question 2 relates to the many revisions associated with the design and construction of the spillway project. There are various changes being considered for continued improvement in the design. Most of the notable planned changes are self-explanatory. Further explanation of some of these features include:

- Chute excavation approaching the headworks: This item deals with how excavation of the foundation rock will occur and to what limit as the work approaches the gated structure.
- The aeration feature is used to add entrained air into the spillway flows to mitigate potential cavitation of the concrete within the spillway. The designers are currently evaluating the need and most efficient design if further aeration is implemented.
- Additions to the Emergency Spillway refer to further design details that are being considered.

The BOC also discusses the cracking that developed on the Flood Control Outlet chute slab. The BOC outlines the reasoning for the occurrence of the cracks. The BOC also concurs with DWR conclusions that the cracks will not affect the spillway performance and outlines the reasoning why the performance would not be affected.

**Question 3**

Question 3 relates to modeling being performed for the FCO and emergency spillways. A physical model refers to the scaled model that was constructed at Utah State University. The computer model refers to computer model that is used to simulate the flows using mathematics. The BOC outlines the features that are being studied using the models including aeration requirements, if any, the optimum geometry and the spillway approach conditions. These models are used to optimize the design prior to actual construction. As noted above, aeration is used to mitigate against potential cavitation.

**Question 4**

Question 4 relates to the in-depth investigation regarding whether roots were a causal factor in the damaged spillway. Based on limited information and no investigations, others outside of the official investigation had concluded that roots clogged drains and were a causal factor in the failure of the spillway slab. Based on the in-depth studies, the BOC concludes that roots were an unlikely factor.

**Question 5**

Question 5 relates to further studies that were completed based on requests by the BOC regarding potential erosion downstream of the secant wall near the emergency spillway. The secant wall is a concrete wall that is being placed beneath the ground and downstream of the emergency spillway. The purpose of the wall is to stop any back cutting of rock before it reaches the emergency spillway structure. Although the BOC believes that erosion downstream of the wall would not occur, they encourage further studies be completed.

The BOC also mentions the underdrains which are being placed beneath the Flood Control Outlet spillway slab. The BOC believes a design should be implemented that will allow future access and inspections into the drains.

# OROVILLE EMERGENCY RECOVERY – SPILLWAYS
# Board of Consultants Memorandum

DATE: December 1, 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. 14

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## INTRODUCTION

On Thursday November 30, 2017, the Independent Board of Consultants (BOC) met at the Department of Water Resources (DWR) Oroville Field Division Office Main Conference Room at 8:00 am for presentations made by DWR and their consultants on updates on the following:

- Construction Status and Planning Update,
- Design Revisions Planning,
- Hydraulics Modeling Update,
- Tree Root Architecture Report,
- Surveillance and Monitoring, Recommissioning, and Comprehensive Needs Assessment Plans, and
- Emergency Spillway Downstream Erosion Potential Assessment.

At 1:00 pm the BOC toured the dam site to observe construction progress. The following construction features were observed:

- Emergency Spillway's new control section at the right spillway abutment,
- Excavation for the Emergency Spillway's roller compacted concrete (RCC) apron,
- Interior of the Flood Control Outlet (FCO) Spillway chute,
- Landside of the FCO Spillway chute (right side of spillway looking downstream), and the
- Downstream end of the FCO Spillway dentates.

Representatives from the DWR Engineering Division, the Division of Safety of Dams (DSOD), the Federal Energy Regulatory Commission (FERC), and industry consultants working on the Oroville Spillway Recovery project attended the meeting and participated in the tour of the dam site.

Descriptions and comments made on the individual presentations are contained in the section that follows.

The BOC met on December 1, 2017 at 8:00 am to deliberate and prepare their report. A reading of the BOC's draft report was made to representatives from DWR Engineering Division, DSOD, FERC, and industry consultants at 11:30 am. The meeting was adjourned at 12:00 noon.

BOC members present were Eric Kollgaard, John Egbert, Kerry Cato, Faiz Makdisi and Paul Schweiger.

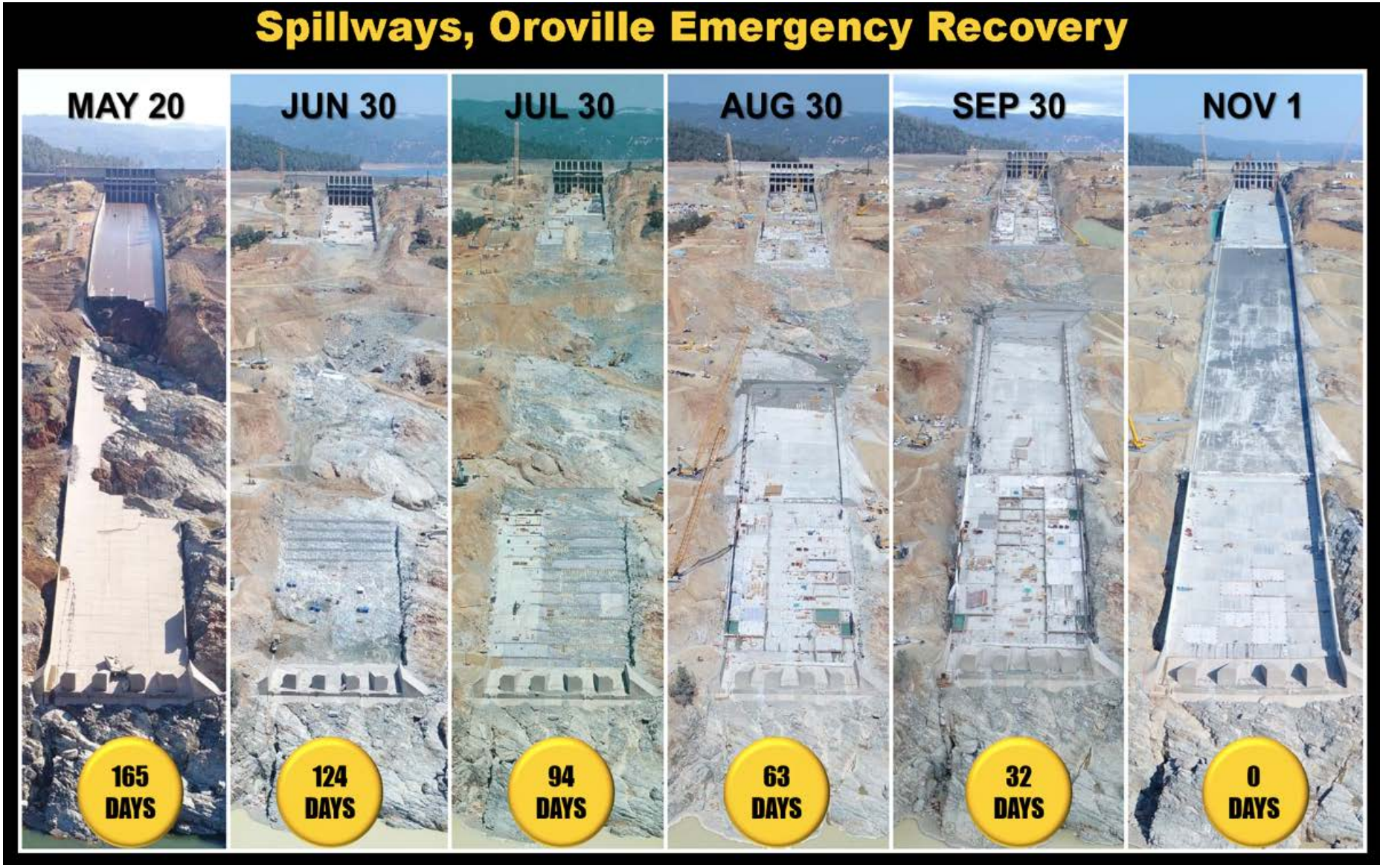
## QUESTIONS FOR THE BOC

1. ***Does the BOC have any recommendations or comments on the construction status and planning update?***

   *Response*

   The BOC congratulates the Design Team, the Contractor, and the regulatory agencies for expediting the project and completing the required construction work by the November 1, 2017 deadline. The completed work is of high quality and the FCO with its interim features is ready for service during the 2017-2018 wet season, if needed. Photographs showing construction progress of the reconstructed FCO spillway are shown in Figure 1.

   The BOC was given an update on the status of the project and planning activities for the 2018 construction year. Construction of the Emergency Spillway modifications is ongoing with concrete placements for the crest wall scheduled for next week. The Emergency Spillway new crest wall is scheduled to be completed in late December. Excavation at the northwest side of the Emergency Spillway for the new RCC apron is ongoing. Excavation on the southeast side of the Emergency Spillway will begin in May. Construction of the FCO spillway modifications is scheduled to resume in May, and potentially earlier if hydrologic conditions permit. The FCO spillway construction is scheduled to be completed by November 1, 2018.



To address concerns with potential shortage of fly ash for the upcoming RCC construction, approximately 70 rail cars of fly ash have been ordered and will be stored at the railyard. The BOC commends the design team for developing and implementing this contingency plan.

**2. *Does the BOC have any recommendations or comments on design revisions planning?***

*Response*

The BOC was given an update on the status of revisions to the design and planning of the project. The Design Team has been updating contract documentation to reflect the current design involving more than 600 submittals and 350 requests for information.

Notable planned changes to the FCO design will include:

- Improving the Erosion Resistant Concrete (ERC) mix design,
- Mitigating hairline cracks observed in the ERC,
- Determining the limits of the chute excavation approaching the headworks,
- Evaluating the need for aeration features, and
- Demolition and disposition of the RCC training walls

Additions to the FCO will include:

- Spillway lighting and permanent camera monitoring,
- RCC access road or crane access for hydro-demolition of damaged surficial concrete at the dentates, and
- Spillway markings for stationing, panel numbering, drain numbering and flow staff gauges.

Changes and discussion regarding the Emergency Spillway include:

- Refinement of the RCC buttress design (smoother crest transition to stepped RCC face),
- Refinement of the secant wall grade beam, and
- Excavation depths and foundation preparation criteria for the new RCC apron will remain as specified.

Additions to the Emergency Spillway include:

- Monolith and buttress drains,
- Horizontal drains under the RCC apron, and
- Evaluating termination detail options for the end of the RCC apron.

The BOC has the following comments and recommendations on design revisions planning:

1. The BOC concurs with the DWR's evaluation, stated in Technical Memorandum SRT-FCO-DOC-09, that the cracking found on many of the structural concrete FCO chute panels is primarily a result of early age volume change caused by autogenous shrinkage and plastic shrinkage. Autogenous shrinkage is defined as a concrete volume change occurring without moisture transfer to the environment and is the result of the internal chemical and structural reactions of the concrete components. The effect is exacerbated by many factors that include: the need for the chute panels to use a high strength concrete mix; the high degree of constraint by the numerous mechanisms employed such as bonding with the leveling course concrete, anchoring to the foundation, interlocking of adjacent panels by continuous bottom mat reinforcement and keyways; the cooling constraints of in-situ panels; and the high ambient climatic temperatures that occurred when the panel concrete was placed.

   The BOC concurs with DWR's assessment that the cracks should be monitored, and that in their current condition, the cracks do not materially impact the structural performance of the FCO chute. The concrete chute is heavily reinforced and anchored to a solid concrete and bedrock foundation. The steel reinforcement embedded within the top of the concrete panels is epoxy coated, thus corrosion is not a concern. The BOC recommends that after the panels reach a state of volumetric equilibrium, a determination be made for the need for remedial measures.

   The BOC agrees with DWR's plans to expand crack investigation efforts to determine and test additional construction measures and concrete mix design changes that could minimize cracking from early age shrinkage in the concrete to be used during the 2018 construction season. The investigation efforts should include an assessment of existing thermal controls.

2. The BOC supports the use of camera surveillance of the FCO chute.

**3. *Does the BOC have any recommendations or comments on the hydraulics modeling update?***

*Response*

The BOC was given an update on the hydraulic modeling and investigations for the FCO and the Emergency Spillways. Both physical model studies conducted at the Utah State University's Water Resources Laboratory and numerical two- and three-dimensional modeling by other consultants are ongoing. Remaining features being modeled include:

- Aeration needs and details for the FCO spillway;
- The optimum geometry for the RCC buttress of the Emergency Spillway control section; and
- Spillway approach conditions for the Emergency Spillway.

In addition to the modeling investigations, the Design Team continues to research aeration features adopted for other similar spillways worldwide.

The BOC remains convinced that additional aeration features are not essential for the permanent FCO Spillway chute configuration. The BOC believes additional aeration may give added confidence that the chute will not be damaged due to cavitation by flows approaching the maximum discharge, if these are ever necessary. The BOC, however, is concerned that the provision for additional aeration could result in excessive bulking of the flows and result in splash over the training walls. The design and construction of aeration provisions also presents added complication to the Contractor's construction schedule for 2018.

The BOC looks forward to reviewing the proposed geometry for the Emergency Spillway RCC buttress and the results of the modeling of the spillway approach conditions with both the FCO and the Emergency Spillway discharging at full capacity during the probable maximum flood.

**4. Does the BOC have any recommendations or comments on tree root architecture?**

*Response*

The BOC was given a detailed presentation on the tree root architecture investigations conducted along the left side of the FCO chute walls. The field investigations were methodically conducted to carefully expose the root systems of different species of trees and brush growing along the FCO chute to determine their extent and potential to intrude, clog, or significantly impact the integrity of the drainage system beneath the FCO chute.

Video surveys found no roots in the interior of the 6-inch perforated vitrified clay pipe (VCP) "herringbone" underdrains. Similarly, no roots were found in the video surveys of the 12-inch VCP outfall/collector pipes along the right side of the FCO chute. Roots were found at 25 locations in the video surveys of the 12-inch VCP outfall/collector pipes along the left side of the FCO chute. The root intrusions consisted of very small roots (e.g. less than a few millimeters in diameter). The maximum outfall/collector pipe area obstructed by roots was estimated to be less than 16 percent of the pipe area.

The preliminary assessment of potential root penetration into the FCO chute underdrain, collector, and outfall pipe systems indicates that limited penetration by small roots (less than 3/8 of an inch in diameter) into the Select Gravel Backfill surrounding the drain pipes is possible and likely. However, the likelihood of significant penetration into the perforated VCP drainpipes is low. Potential impacts of root penetration into the underdrain/collector drain system were concluded to be small and would not have significantly impacted the capacity or integrity of the drainpipes.

The BOC agrees with the overall assessment that it is unlikely that the roots of the trees growing along the length of the FCO chute have significantly impacted the capacity or integrity of the drainpipes. The BOC believes that it is good practice to not allow trees to grow along drain systems of hydraulic structures and recommends that all trees and brush growing along the FCO chute be removed, and that this zone be maintained clear of woody vegetation.

**5. Does the BOC have any other recommendations or comments?**

*Response*

1. The BOC appreciates the Design Team's response to the BOC's request for investigations into the conveyance of the Emergency Spillway flows downstream of the secant pile cutoff wall to the Feather River, and assessing the anticipated extent of erosion of the overburden and weathered rock material within this zone due to various flood events up to the PMF. Based on the update of the preliminary erosion assessment downstream of the secant pile wall, it appears that it is unlikely that the Emergency Spillway outflows could erode a channel that would adversely impact the FCO chute. The BOC encourages the Design Team to confirm this finding with additional subsurface exploration and analyses. The BOC also recommends that the Design Team quantify the amount of overburden and weathered bedrock that is anticipated to be eroded, or which could be excavated as a preemptive measure, in the event the Emergency Spillway is activated to pass large flows up to the full PMF, and to evaluate what impact this would have on the conveyance capacity of the Feather River and the operation of the hydropower facility and outlet works of Oroville Dam. This information will be useful for the Comprehensive Needs Assessment study that will be conducted in the spring and summer of 2018. The BOC believes the Comprehensive Needs Assessment is important and should evaluate if improvements to the channel downstream of the Emergency Spillway or another approach should be pursued to safely convey flows up to the PMF.

2. The BOC continues to believe that flows from the FCO chute underdrains will be low and difficult to accurately measure with the proposed visual method. As an alternative, the BOC suggests that the Design Team consider lowering the elevation of the proposed backfill on the landside of the FCO chute walls below the drain outlets so that the ends of the drain collector outlet pipes are exposed and can be equipped with a modified cleanout that can be opened to measure the flows in the drain pipes with a bucket and stopwatch. This could be accomplished by replacing the vertical sweep cleanout with a threaded end cap. This proposed alternative has the added advantage of facilitating ROV inspection of drain pipes.

3. The BOC was given a presentation on the Draft Spillway Recommissioning Manual and the Draft Dam Safety Surveillance and Monitoring Plan

(DSSMP). The BOC appreciates updates on these plans and awaits the completion of these documents for their review.

## BOC RECOMMENDATIONS SUMMARY

M14-1 The BOC recommends that after the FCO panels reach a state of volumetric equilibrium, a determination be made for the need for remedial measures regarding the concrete cracks.

M14-2 The BOC agrees with DWR's plans to expand crack investigation efforts to determine and test additional construction measures and concrete mix design changes that could minimize cracking from early age shrinkage in the concrete to be used during the 2018 construction season. The investigation efforts should include an assessment of existing thermal controls.

M14-3 The BOC believes that it is good practice to not allow trees to grow along drains systems of hydraulic structures and recommends that all trees and brush growing along the FCO chute be removed, and that this zone be maintained clear of woody vegetation.

M14-4 The BOC encourages the Design Team to confirm that the Emergency Spillway flows would not adversely impact the FCO with additional subsurface exploration and analyses.

M14-5 The BOC recommends that the Design Team quantify the amount of overburden and weathered bedrock that is anticipated to be eroded in the event the Emergency Spillway is activated to pass the full PMF, and to evaluate what impact this would have on the conveyance capacity of the Feather River and the operation of the hydropower facility and outlet works of Oroville Dam.

M14-6 The BOC believes that flows from the FCO chute underdrains will be low and difficult to accurately measure with the proposed visual method. As an alternative, the BOC suggests that the Design Team consider lowering the elevation of the proposed backfill on the landside of the FCO chute walls below the drain outlets so that the ends of the drain collector outlet pipes are exposed and can be equipped with a modified cleanout that can be opened to manually measure the flows in the drain pipes.

Respectfully submitted,

**Eric B. Kollgaard**

**Faiz Makdisi**

**Kerry Cato**

**John Egbert**

**Paul Schweiger**