OROVILLE EMERGENCY RECOVERY – SPILLWAYS
Board of Consultants Memorandum

DATE: April 24, 2018

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

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

SUBJECT: Memorandum No. 17

INTRODUCTION

On Monday April 23, 2018, 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 the Department of Water Resources (DWR) and their consultants on updates for the following:

- Flood Control Outlet (FCO) chute research program;
- Project Design Report;
- Construction progress briefing and tracking;
- FCO chute longitudinal drains and exterior wall pervious backfill;
- Cast-in-place concrete laboratory mix design proportioning studies and placement modifications for 2018 construction; and
- 2018 construction season Gate Closure Plan update.

At 9:30 am, the BOC, representatives from the DWR Division of Engineering, the Division of Safety of Dams (DSOD), the Federal Energy Regulatory Commission (FERC), DWR Division of Operations and Maintenance, and industry consultants working on the Oroville Spillway Recovery project toured the dam site to observe construction progress. The following construction features were observed:

- roller-compacted concrete (RCC) placement for the Emergency Spillway apron;
- excavation for the Phase 2 RCC for the Emergency Spillway's buttresses
- trimming of the secant pile cutoff wall; and

- hydro-demolition of damaged concrete surfaces for the rehabilitation of the FCO dentates.

At 11:30 am, the BOC returned to the Oroville Field Division Office Main Conference Room for additional updates on:

- design of the FCO longitudinal drains and pervious backfill;
- Emergency Spillway apron stability analysis;
- Emergency Spillway apron drains;
- Emergency Spillway buttress stability analysis summary; and
- Emergency Spillway buttress foundation drains.

On Tuesday April 24, 2018 at 8:00 am, the BOC met at the Oroville Field Division Office Main Conference Room to deliberate and prepare their report. Descriptions and comments made on the individual presentations and the BOC's responses to the DWR questions are included in this report.

A reading of the BOC's draft report was made to representatives from DWR Engineering Division, DSOD, FERC, DWR Division of Operations and Maintenance, and industry consultants working on the Oroville Spillway at 12:00 pm. The meeting was adjourned following the reading of the report. 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 update or site visit?***

   Response

   The BOC is pleased with the continued construction progress being made at the Emergency Spillway. Placement of the RCC apron which commenced on February 28, 2018, continues to progress well with approximately 115,000 cubic yards of the estimated 590,000 total required cubic yards of RCC placed. Construction milestones since the BOC meeting of last March include:

   - commenced excavation in Emergency Spillway area 2A;
   - began hydro-demolition at FCO dentates;
   - obtained source of fly-ash for RCC; and
   - completed FCO Gate Closure Plan.

Photographs of RCC construction work observed by the BOC are presented on Figures 1 and 2.

The opportunity to inspect both sides of the upper 25 feet of the unearthed section of the secant pile cutoff wall located at the left side of the Emergency Spillway is unusual since these types of walls are seldom exposed for observation. The BOC was pleased with the constructed wall.

The BOC believes the planned June shutdown of the RCC processing plant and RCC placing operations may have an adverse impact on the scheduled construction of the Emergency Spillway RCC apron and buttress by November 1st, 2018. The BOC agrees with the Design Team that repair or replacement of the damaged aggregate crushing plant equipment needs to be expedited.

2. Does the BOC have any recommendations or comments on the Gate Closure Plan?

Response

The primary objective of the Gate Closure Plan is to ensure public safety by maximizing the 2018 construction window to ensure the FCO is fully reconstructed prior to next winter. Beginning reconstruction of the FCO as early as possible is desirable to meet this objective.

According to the latest April through July weather forecast, the total runoff into Oroville Reservoir will be between 800 and 1,340 thousand acre-feet, which is well below the historical average of 1,704 thousand acre-feet. Based on this forecast, the Design Team is planning for a May 8 seasonal FCO gate closure date. Inflows produced by late season precipitation and snowmelt can be adequately released through the Hyatt power plant and the dam's outlet system. The Design Team is targeting normal water supply targets for the end of September consisting of 1.3 million acre-feet of remaining storage corresponding to a lake elevation of approximately 710 feet MSL. Additional drawdown in October would lower the lake elevation to approximately 700 feet MSL by the November 1 FCO completion date.

Figure 1. Aerial photographs of the Emergency Spillway Construction (Top), and Emergency Spillway RCC Apron Construction (Bottom)

Figure 2. Photographs showing exposed secant pile cutoff wall at left side of the Emergency Spillway (Top) and Hydro-demolition work for rehabilitation of the Dentates at the downstream end of the FCO Chute

The reservoir is currently at approximately Elevation 814 feet MSL; approximately 1-foot above the sill of the gated FCO control structure. The FCO gates are closed. Access to the FCO chute is "over the wall". This will be the case until Oroville Dam operations allow an open gate for easier contractor access. Alternatively, access to the FCO chute may be made by demolition of a portion of the RCC shoulder wall or of the structural spillway wall to be replaced. The BOC agrees with the Gate Closure Plan.

The BOC also concurs with the Design Team's assessment that water infiltration into the FCO work area due to gate seepage (20 to 30 gpm) and elevated groundwater levels, can be contained by the contractor and pumped back to the reservoir, and that construction within the upper FCO chute can be performed safely. The BOC understands that, given "Reservoir Operations" forecasts of the April through July runoff, and the scheduled releases through the Hyatt powerhouse and through the low-level river outlet valve, the anticipated reservoir level is expected to be drawn down below the bottom sill of the FCO gated spillway by the time FCO concrete construction commences.

3. *Does the BOC have any recommendations or comments on design modifications?*

Response

FCO Spillway Concrete Mix Design. The BOC has been following the Design Team's efforts to improve the 2017 Erosion Resistant Structural Concrete (ERC). The goal is to reduce both shrinkage cracks and excessive temperature gradients in the placed concrete slabs. This task involves a "*Systems Approach*" which, when complete, will modify the 2017 ERC mix design and improve the methods and controls for placing and curing the concrete.

The BOC appreciates the current update by the Design Team to improve both the ERC mix design using the "*2018 ERC Mix Design Laboratory Program*", and the associated concrete placement and control measures to minimize concrete shrinkage cracking. The preliminary test results shared with the BOC appear to show significant improvements in the concrete mix design by maximizing the volume of coarse aggregate, minimizing the volume of fine aggregate, minimizing the cement paste content (cement, pozzolan and silica fume), and potentially adding shrinkage-reduction and expansive-cement additives to minimize concrete shrinkage cracking.

The BOC was advised that a test slab will be placed on or about May 4 using a concrete mix designated as “2018 ERC 520” (Type 2 Cement without additives) for half of the test slab, and a mix design substituting 20 pounds per cubic yard of Komponent for 20 pounds of Type 2 Cement for the other half of the test slab. The BOC looks forward to reviewing the test results for the recommended mix design together with the suggested placement improvements, and reviewing the results for the test slab.

The BOC understands that the Design Team is considering adjusting the top reinforcing steel mat clear cover from 4 inches to 3 inches. The BOC concurs with this adjustment.

Emergency Spillway Apron Stability. A stability evaluation was made for the Emergency Spillway RCC apron. Conservative one-dimensional infinite slope stability analyses were conducted for the steepest portion of the apron using both worst case lower strength values and “most appropriate” shear strength values based on assumptions for the foundation materials. Cohesion was ignored in all cases. The foundation for the apron varies from decomposed rock near the secant wall to slightly weathered rock as the foundation area approaches the upstream spillway crest control section. Only limited areas appear to have small amounts of fine grained material left after the grading and foundation cleaning by brush sweeping. The apron will have vertical drilled drains installed through the RCC apron and foundation which will limit the uplift pressure from ground water that could act at the base of the apron. The results of the analyses indicate sliding Factors of Safety above 3.3 for all foundation strength cases with zero uplift pressure. A sensitivity analysis assuming various uplift scenarios was also performed. A Factor of Safety of 1.9 was determined for an assumed uplift pressure of 15 feet of water under the RCC apron. In all cases the factors of safety against sliding exceed the minimum required factor of safety criterion of 1.5. The BOC concurs that the stability of the RCC apron is acceptable.

Emergency Spillway Monolith Stability. The BOC received a lengthy Technical Memorandum (TM) documenting the stability analyses performed for the Emergency Spillway monoliths shortly before this meeting. Therefore, the BOC members have not all had the opportunity to review this material in detail. However, a presentation on the subject was made during the meeting which provided an excellent summary of the analyses including the following:

- selection of the monoliths for analysis;
- foundation conditions and evaluation of strength properties;

- delineation of the analysis methodology employed;
- stability criteria, loading assumptions and uplift determinations that apply; and
- Factors of Safety against sliding for both the existing structure and the remediation design of the monoliths with the RCC buttresses.

The Design Team indicated that the slightly weathered to fresh rock foundation beneath the Emergency Spillway monoliths consists of relatively high quality and high strength rock, and that potential sliding failure modes associated with rock mass strength, buckling, or discontinuities, have a low probability of occurrence. The BOC concurs with this assessment, and agrees that the governing condition to be analyzed for stability is sliding on the concrete-bedrock foundation interface.

The sliding Factors of Safety at the base joint of the existing monoliths were reported as shown in Table 1.

Table 1
Sliding Factors of Safety at Bedrock-Concrete Interface (Existing Monoliths)

Load Case	Monolith [redacted] Sta. [redacted]	Monolith [redacted] Sta. [redacted]	Monolith [redacted] Sta. [redacted]	Monolith [redacted] Sta. [redacted]	Monolith [redacted] Sta. [redacted]
Case 1 – Usual Loads	4.43	3.03	2.28	1.85	2.33
Case 2 – PMF	2.13	0.72	0.50	0.44	1.15
Case 3 – Post Seismic (Residual Strength)	1.53	1.08	0.90	0.76	1.15

The BOC believes the analysis assumptions, while generally conservative, are reasonable and all factors have been properly accounted for. It can be seen that some of the taller existing monoliths exhibit unsatisfactory factors of safety under the PMF loading. The remediation by buttressing the downstream side of the monoliths as planned in the design is entirely justified and necessary.

The stability analyses of a monolith buttressed by mass concrete on the downstream face is a much more difficult problem, particularly under seismic loading because of the uncertainty of the behavior of the composite structure, whether it acts as a unified body or as separate entities. The Design Group performed calculations for various behavior cases and have carried out sensitivity analyses. Table 2 shows the sliding Factors of Safety at the base joint (bedrock – concrete interface) of the modified monoliths.

Table 2
Sliding Factors of Safety at Bedrock-Concrete Interface (Modified Monoliths)

Load Case	Monolith 8 Sta. 21+68	Monolith 13 Sta. 23+93	Monolith 16 Sta. 25+28	Monolith 18 Sta. 26+18	Monolith 19 Sta. 26+62
Case 1 – Usual Loads (Peak Strengths)	5.53	3.89	3.59	3.59	5.02
Case 2 – Unusual (PMF) (Peak Strengths)	2.44	1.97	2.19	2.38	3.34
Case 3 – Extreme (Post Seismic) (Residual Strengths)	2.98	2.05	1.94	2.21	3.28

The BOC believes the analyses have been carried out using very conservative assumptions and demonstrate that the stability of the modified monoliths as presented in the Design Memorandum is entirely satisfactory. The BOC complements the Design Team for the excellent solution to a difficult stability study. The BOC notes that the stability of the Emergency Spillway monoliths is not dependent upon the operation of existing base drains in the monoliths or the addition of drains in the RCC buttress section downstream of the monoliths. The BOC believes that the existing and proposed drain systems are still important and recommend keeping them in the current design plan with appropriate cleanouts.

Drains at the RCC Section to Address Seepage through Existing Cracks. The Design Team presented proposed designs for installing longitudinal drains that would intercept and collect seepage currently observed through cracks in the RCC surface in the vicinity of Station 33+00 (seeps 21C, 22C, 61C, and 62C). These longitudinal drains will be extended to connect to currently designed adjacent transverse drains. The BOC concurs with the proposed addition of these drains, as well as the proposed lengthening of rock anchors at this shallow section of the RCC foundation.

Modifications to Pervious Backfill behind FCO Training Walls. The BOC concurs with the proposed design modifications that included minor adjustments to the filter gradation, and a simplification of the zone placements by removing the “general fill” and including it as a subset of the “common fill.” The proposed gradation changes do not affect the compatibility between the filter and drain.

4. Does the BOC have any other recommendations or comments?

Response

Emergency Spillway Foundation in Areas 2 and 3. The BOC observed initial excavation underway in Area 2 upstream of the secant pile cutoff wall. The BOC believes there is still uncertainty regarding amount and depth of required excavation and how this could impact the quantity and schedule for RCC backfill placement in both Areas 2 and 3.

Contractor's Preparation of FCO for Upcoming Construction. In anticipation for upcoming construction, the Contractor is constructing crane pads in both the upstream and downstream areas of the FCO. Although not observed, the contractor is testing the milling operation and procedures that will be used to prepare the RCC surface for placement of the ERC slabs. The BOC was gratified to hear that the test indicated that the observed milled surface was favorable with minimal displacement or spalling of surface aggregates.

Final Comment. The BOC continues to be impressed with the sustained intense level of design, planning, and execution of the emergency modifications to the Oroville FCO and Emergency Spillway. The completed work since the spillway incident occurred thirteen months ago is remarkable. The communication and cooperation between the Design Team, the contractor and the regulatory agencies is to be commended.

BOC RECOMMENDATIONS SUMMARY

None

Respectfully submitted,

Eric B. Kollgaard **Faiz Makdisi** **Kerry Cato**

John Egbert **Paul Schweiger**