OROVILLE EMERGENCY RECOVERY – SPILLWAYS
Board of Consultants Memorandum

DATE: March 29, 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. 16

INTRODUCTION

On Wednesday March 28, 2018, the Independent Board of Consultants (BOC) met at the Parks and Recreation Office, at 400 Glen Drive, Oroville at 8:00 am for presentations made by the Department of Water Resources (DWR) and their consultants on updates for the following:

- 2018 construction season gate closure, and
- Construction progress briefing and tracking.

At 9:00 am, the BOC toured the dam site to observe construction progress. The following construction features were observed:

- Roller-compacted concrete (RCC) placement in the new Emergency Spillway apron; and
- Core samples of the RCC, leveling concrete and foundation bedrock from the FCO spillway RCC section.

At 11:30 am, the BOC returned to the Parks and Recreation Office for additional updates on:

- Geology investigations;
- Modifications to the concrete mix design;
- FCO spillway aeration;
- Ogee Emergency Spillway RCC buttress and drainage system; and
- Emergency Spillway apron stability and foundation drains.

On Thursday March 29, 2018 at 8:00 am, the BOC met at the Parks and Recreation Office for additional updates on:

- Design modifications, plans and specifications; and
- Left FCO Spillway Walls 97A, 98A, and 99A.

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 attended the meetings and participated in the tour of the dam site. Descriptions and comments made on the individual presentations and the BOC's responses to the DWR questions are contained in the section that follows.

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 12:15 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 ongoing construction?***

   Response

   2018 Construction Schedule. The BOC has confidence that the Contractor and Design Team are taking appropriate actions to complete the remaining work by November 1, 2018. DWR's monitoring of the snowpack, direct runoff, changes in the lake level, weather forecasts, and detailed statistical analyses of historical lake inflows show that risks associated with a late storm event are being thoughtfully considered in the planning of future work. The BOC understands that the April snowpack determination is a critical factor in forecasting and planning Oroville Dam operations which will, in turn, impact the Contractor's access to begin work in the FCO spillway. The reservoir is currently at approximately Elevation 780 feet MSL.

   The BOC is in favor of beginning the 2018 construction work within the FCO Spillway chute earlier than planned if the analyses show that the risk is being adequately managed. The FCO gates are now closed and therefore 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.

Left FCO Spillway Walls 97A, 98A, and 99A. Between Stations 41+30 and 42+50, left spillway wall panels 97A, 98A and 99A were constructed outside of the specified vertical tolerance. The alignment of the walls at their base with the chute slab is true, however the 20.8-foot-high wall tilts inward by a maximum of 4.7 inches at the top. The Design Team evaluated the potential consequences of both demolishing and rebuilding the walls, as well as accepting the walls as constructed. The Design Team's analysis of the flow hydraulics and structural integrity of the walls shows that the FCO spillway will perform satisfactorily as constructed. The Design Team believes that demolishing and re-constructing the wall sections would ultimately result in an overall lower quality structure, and recommends that the walls be accepted as constructed. The Design Team and Contractor determined the cause of the problem and have taken effective action to assure it is not repeated.

The BOC believes that it is in the best interest of the project not to demolish and reconstruct the walls, and concurs with the Design Team's recommendation to leave the walls in place. The BOC believes that this anomaly will not materially impact the performance or integrity of the FCO spillway.

Construction of the Emergency Spillway RCC Apron and Secant Pile Wall. The BOC is pleased to see the construction progress being made at the Emergency Spillway. Construction of the cutoff wall and secant pile wall have been completed. Placement of the RCC apron which commenced February 28, 2018 is progressing well. RCC placement began at the low point in the Secant Pile Wall (Station 15+50 to Station 16+00) and is progressing uphill and outward. Foundation preparation continues in an uphill direction. Upon acceptance, the foundation is immediately covered with a lift of RCC. The contractor in on track to complete the RCC apron in mid-August. Photographs of RCC construction work observed by the BOC are presented on Figure 1.

The BOC concurs with the decision to use sloped RCC steps (1H:1V) instead of vertical RCC steps. The RCC is placed in one-foot-thick lifts (two consecutive lifts per step) and compacted with a vibratory plate compactor attached to an excavator. The BOC understands that the specified compaction is being achieved.

Figure 1. Photographs Showing RCC Apron (Top) and Secant Pile Wall (Bottom)

The BOC concurs that the filtered drain detail under the RCC apron that penetrates the secant pile wall is adequate to transmit seepage that could accumulate. The BOC recommends frequent monitoring of flow out of the drain pipe to help assess ground water conditions beneath the apron, and the effectiveness of the vertical drilled drains to be installed through the RCC section.

2. ***Does the BOC have any recommendations or comments on pending design refinements?***

Drilled Foundation Drains in Emergency Spillway RCC Apron. The BOC concurs with the proposed design details for the drilled foundation drains in the Emergency Spillway RCC apron. The BOC recommends that the outlet at the top of the vertical drains be equipped with a check valve or backflow prevention device. This will also eliminate the need to install animal guards.

RCC Buttress and Toe Drains at Emergency Spillway Ogee Monoliths. The BOC concurs with the proposed design refinements to the RCC buttress and toe drains. The Board recommends that any detailed design of the drainage system for the buttress at the deep monoliths be finalized after excavation of the backfill covering the existing drains and outfalls for these monoliths is completed.

FCO Spillway Concrete Mix Design. The BOC is pleased with the progress made by the Design Team to improve the erosion resistant concrete (ERC) mix design and the associated concrete placement and control measures to minimize concrete shrinkage cracking. The BOC understands that trial batch testing of the proposed improved ERC mix design is nearly complete. The BOC looks forward to reviewing the test results of the recommended mix design together with the suggested placement improvements.

FCO Spillway Chute Grouted Slab Anchors. The BOC concurs with the proposed modification in the number of 25-foot long grouted slab anchors shortened to 15-foot-long anchors in the FCO chute in areas where the anchors would only be attached to RCC. Based on the Design Team's analysis of the foundation treatment and geology using the 25-foot long anchors in reaches founded in natural rock materials is appropriate and a good use of resources.

Aerators for the FCO Spillway Chute. The BOC is satisfied with the Hydraulic Design Team's efforts to investigate the need for aerators for the FCO Spillway chute, and is pleased with the input solicited from outside experts on this

important issue. The BOC concurs with the Hydraulic Design Team's four recommendations regarding aerators for the FCO Spillway chute, including:

1. *Construct the FCO Spillway during the 2018 construction season without an aeration spillway slab step, but provide measures for future modifications to include an aeration device with a five-foot vertical step in the vicinity and downstream of STA 31+00.*

2. *Pursue a research project with input from experts to further evaluate the need for aeration of the FCO Spillway. This research will provide the best solution for the FCO and will be shared with the dam safety community and the public.*

3. *Use instrumentation to monitor the performance of the FCO Spillway during future spillway release events and carefully inspect for signs of incipient cavitation damage after large discharges.*

4. *Modify the spillway in the future to complete implementation of the aeration device at approximate STA 31+00 if future research and performance evaluations find it necessary.*

Source: FCO Spillway Evaluation Summary and Recommendation for Aeration Technical Memorandum dated March 23, 2018 with some edits by BOC.

The plan to defer the decision on adding aeration provisions until the performance of the FCO Spillway demonstrates that this would be necessary is, in the opinion of the BOC, validated by the experience at the very large Itaipu hydroelectric project in Brazil. This 643-foot-high dam constructed in 1982 uses a steep chute spillway which was constructed with air inlet chimneys. Construction of the air slots in the chute were intentionally omitted. It was decided during the design phase to rely on a high-quality surface finish of the concrete chute and only complete the aeration provisions in the chute if operational experience demonstrated this would be necessary. The spillway has undergone 36 years of operation passing four discharge events greater than 600,000 cfs. The chute operated continuously for the first 8 years of operation. There have been no problems with significant cavitation damage. It is reported that a few concrete patching repairs in the chute had popped out and had produced a very limited amount of damage immediately downstream of an offset to the flow at the end of the chute upstream of the flip bucket. Photographs of the Itaipu spillway are presented in Figure 2.

Figure2. Photographs of Itaipu Spillway (Source Wikipedia)

The BOC recommends that the Hydraulic Design Team begin working on the research project features with the assistance of outside experts as soon as possible since some of the potential testing features, like water taps for measuring air entrainment, may require embedment within the new concrete slabs and walls.

As part of the proposed research project to evaluate the need for aeration of the FCO spillway, the BOC recognizes that the FCO spillway may not experience significant flows for several years to come, and possibly longer. The BOC therefore suggests that the Hydraulic Design Team's research project be sensitive to this factor and include provisions to collect meaningful data for lower, more frequent flow events. For example, the research project could include installing temporary removable [redacted] strategically placed within the FCO chute that could be used to test for cavitation for relatively low flow conditions within the spillway. These removable [redacted] could be monitored for short controlled flow periods to determine if self-aeration is effective in preventing cavitation damage. If cavitation damage is not observed, this will provide empirical information that self-aeration is effective in preventing cavitation damage. If cavitation damage is observed, the [redacted] could be removed to prevent cavitation damage and allow the FCO spillway to continue to operate as intended. The need for aerators would then be made and incorporated into the FCO as needed. While it has been assumed that the aerator will be located downstream of STA 31+00, this is based on the "general feeling" that this is the best location. The optimum aerator location should be based on specific site data.

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

Response

Additional Geological Investigations. The BOC was provided a Technical Memorandum (SRT-ORO-GO-12E R1) that describes the planned additional geotechnical borings in the area upstream of the Emergency Spillway weir. The BOC endorses this additional exploration program. The current plan includes installing vibrating wire piezometers to provide data on an hourly basis. The Board recommends readings be obtained less frequently (say on the order of every 6 hours) to extend the life of these units across more wet seasons.

FCO Seep Investigation. The results of the Design Team's investigation into the cause and source of the water seeps, through the RCC in the FCO spillway (right side at STA 33+00 to 33+50), indicate some seepage travels along bedrock discontinuities from known nearby sources, while other sources cannot be identified. It is no surprise that groundwater pathways in a bedrock fracture flow regime can be complicated, and identifying the source these flows may not be that critical. It is more important to note that the flows are low (less than a half a gallon per minute) and were observed to dissipate shortly after precipitation events. Permanent vibrating wire piezometers were installed to monitor bedrock and concrete groundwater conditions at this location. The BOC believes getting and maintaining these piezometers in a reliable operating condition is helpful during future precipitation events and FCO spillway flows. The BOC believes that the planned remediation (drains in the RCC to intercept the seeps that are plumbed into the existing drain system) is appropriate and advisable.

Emergency Spillway RCC Apron. During the inspection of the Emergency Spillway repair (at this meeting [BOC Meeting #16] and at the inspection a month ago [BOC Meeting #15]), the BOC observed cleanup operations and RCC placement at the right side of the RCC apron foundation. The uppermost and almost flat slope of the RCC apron (from the broad-crested weir extending downstream for approximately 250 feet) consists of a slightly weathered to fresh rock surface obtained by blasting and rock ripping. Further downstream, the excavated RCC apron foundation surface slope ranges from 9 to 11 degrees. This portion of the excavated slope is more weathered, ranging from a moderately weathered to slightly weathered rock surface. The BOC observed RCC placement at the lowest areas adjacent to the secant wall. In some areas RCC placement has progressed about 150 feet upstream of the wall.

The BOC was given a presentation on RCC apron sliding stability. The BOC recognizes the preliminary nature of this analysis and that an updated and more rigorous analysis will be presented at the next BOC meeting. The shear strength parameters to be used in the stability analyses should be consistent with the observed and documented quality of the rock exposed in the excavated foundation. The BOC recommends that any residual soil that is not consistent with the quality of bedrock assumed in the stability analysis should be removed prior to placement of the RCC.

The BOC was given a presentation on proposed vertical drains in the RCC Apron. The BOC believes the addition of these drains is prudent, however cautions that check valves should be used to prevent entrance of spillway flow

into the drains. The BOC further endorses the concept that the location of the drains be controlled by both the general distribution of some drains, while other drains should be specifically located to coincide with known seep locations on the bedrock surface.

BOC RECOMMENDATIONS SUMMARY

M16-1 The BOC recommends that the Hydraulic Design Team begin working on the aerator research project features with the assistance of outside experts as soon as possible since some of the potential testing features, like water taps for measuring air entrainment, may require embedment within the new concrete slabs and walls.

M16-2 The BOC recommends vibrating wire piezometer readings in the Emergency Spillway be obtained less frequently than every hour as proposed (say on the order of every 6 hours) to extend the life of these units across more wet seasons.

M16-3 The BOC recommends that any residual soil on the Emergency Spillway Apron foundation surface that is not consistent with the quality of bedrock assumed in the stability analysis be removed prior to placement of the RCC.

M16-4 The BOC recommends that check valves be used on the vertical drains installed in the Emergency Spillway RCC apron.

Respectfully submitted,

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John Egbert **Paul Schweiger**