

OROVILLE EMERGENCY RECOVERY – SPILLWAYS

Board of Consultants Memorandum

DATE: October 11-12, 2018

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

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

SUBJECT: Memorandum No. 21

INTRODUCTION

On Thursday October 11, 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 and departed soon afterwards, with 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, to tour the Oroville Dam Site and observe construction progress since the last BOC meeting held on September 5 and 6, 2018.

The following construction features were observed:

- Construction of chute slabs and walls in the upper section of the FCO chute (see Figure 1).
- Construction of chute slabs, walls, and drain pipes in the middle and end sections of the FCO chute (see Figures 2, 3 and 4).
- Final placement of reinforced concrete to rehabilitate the FCO terminal structure (see Figure 5).
- Test section for the 2H:1V conventional concrete transition section at the top of the RCC stepped buttress for the Emergency Spillway Ogee section (Figure 6).
- RCC apron, drains and buttress of the ogee monoliths for the Emergency Spillway (see Figure 7).



Figure 1. Construction of chute slabs and walls in the upper section of FCO chute.



Figure 2. Construction of wall drains in the middle section of FCO chute (middle right side).



Figure 3. Construction of chute slabs, walls and drains in the middle sections of FCO chute (lower right side).



Figure 4. Reconstruction of the terminal structure and backfill along the end section of FCO chute (end of right side).



Figure 5. Reconstruction of the dentates at downstream end of FCO chute.



Figure 6. Test section for the 2H:1V conventional concrete transition section at the top of the RCC stepped buttress for the Emergency Spillway Ogee section.



Figure 7. RCC apron, drains, and butress of the ogee monoliths for the Emergency Spillway.

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

- Construction progress update.
- Site grading design plan.
- Geology and foundation preparation update.
- Groundwater monitoring plan.
- 2018/2019 Reservoir Operations Plan.
- Hydrology and hydraulics update.
- Spillway approach loss analysis.
- Emergency Spillway buttress hydraulics.
- Spillways Surveillance Plan.
- FCO surface treatment plan.
- Spillway drain video inspection plan.

On Friday October 12, 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 at 12:00 noon to representatives from DWR Engineering Division, DSOD, FERC, DWR Division of Operations and Maintenance, and industry consultants working on the Oroville Spillway. 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 progress and site visit?***

Response

Substantial progress has been made since the last BOC visit to the site on September 6, 2018. Construction of most features is near completion. It appears to the BOC that the critical elements of the project will be completed before November 1, 2018. The BOC cautions that projected completion schedule of the

RCC Buttress and Erosion Resistant Concrete (ERC) cap in the Emergency Spillway by November 1 may be optimistic. This work includes placement of the RCC buttress and the ERC cap detail at the top of the RCC buttress. Notwithstanding, the BOC congratulates the Design Team, contractor and regulators for this momentous accomplishment.

Based on the inspection of the test section for the 2H:1V conventional concrete transition section at the top of the RCC stepped buttress for the Emergency Spillway Ogee section (see Figure 6), the BOC concurs with the Design Team's decision to use slip-forming or screeding instead of conventional forming to provide the best finished surface.

2. Does the BOC have any recommendations or comments on the preliminary site grading plan?

Response

A presentation was made on the preliminary site grading plan. The preliminary site grading plan includes removal of portions of the Contractor's crane pads and placing fill in strategic locations along the FCO chute to facilitate continued placement of pervious backfill behind the chute walls. Before the site grading plan can be undertaken, review and approval of the plan is required from the FERC and environmental authorities. A considerable volume of fill material is involved in the final grading plan and is estimated to approach a million cubic yards of material. Much of this fill will come from removal of the RCC plant staging area and the waste disposal site of material dredged from the river.

The contractor started placing pervious backfill along the FCO chute training walls, and until the site grading plan is approved, may need to place a local berm to suit the elevation of the grading plan along the portions of the chute length to provide restraint for the backfill material. This option is shown on the approved backfill design drawings.

It was stated that some of the FCO drainage piping that was installed last year and was exposed to the elements had suffered damage that needed repair. Expansion provisions have been added to the piping to alleviate this problem, but care should also be taken that turbid water and sediment from runoff during rain storms does not accumulate within the perforated drain pipe. In some parts of the chute length an initial placement of pervious backfill should be considered to cover and protect the pipe until the final fill grade is reached.

The BOC was informed that the Contractor has begun demobilizing equipment no longer needed to construct the project. The BOC recommends that the Design Team review the future construction work associated with the site grading plan to determine if any of the remaining features should be constructed early to make best use of the Contractor's resources before they are demobilized, such as the RCC, conventional concrete, and rock aggregate crushing plants, or other specialized onsite equipment. A possible need for RCC may be the planned permanent access road where it crosses below the terminal structure of the FCO.

The BOC endorses the plan to locate the permanent Boat Ramp Access Road outside the footprint the Emergency Spillway apron and control structure.

3. Does the BOC have any recommendations or comments on foundation preparation and groundwater monitoring plan?

Response

The only foundation preparation observed during the BOC site tour was in Area 3 of the Emergency Spillway downstream of the ogee monolith sections. All foundation areas in the FCO chute spillway have been covered by reinforced concrete, with the final concrete panel placement occurring during the BOC meeting. The BOC commends DWR and the construction team for achieving this milestone ahead of schedule. At the Emergency Spillway, the BOC observed final cleanup of the monolith drain foundation and backfill of the drainpipe. The foundation preparation and placement of drains are being installed as per specifications and to accommodate excavated site conditions and the BOC is pleased with this effort.

A presentation on the groundwater monitoring plan, as well as a summary of the site groundwater conditions, was made to the BOC. At the Emergency Spillway, new groundwater monitoring wells will be installed immediately upstream of the secant wall. New and replacement piezometers will be placed in the apron area along identified shears. Vertical drains for the slab are being installed in both a pattern arrangement, as well as at observed seep areas in the apron. These drains will serve as additional groundwater monitoring points beneath the RCC apron of the Emergency Spillway. Monitoring wells exist outside and along the FCO spillway and in the hill to the left of the FCO. These wells should continue to be monitored and their data analyzed. The BOC believes this is an adequate groundwater monitoring plan and believes the plan exceeds the monitoring programs at most other dams.

A summary of the groundwater conditions in and around the spillways indicates there is a strong correlation between groundwater levels and precipitation. The groundwater data collection and monitoring effort began after the February 2017 event and extended over the 2017-2018 wet season. The BOC notes that precipitation during this past winter was relatively low. The BOC encourages DWR to continue this monitoring effort into the near future where: (1) the effects of at least one wet season with high precipitation can be recorded by the instrumentation; and (2) the effects of a FCO flow event (and associated high reservoir water level) on the groundwater regime can be observed and documented. One issue in this program may be instrument operability. For example, vibrating-wire piezometers in the FCO chute may only have a service life of 5 years. The BOC notes that the finite life of many groundwater monitoring instruments creates a window in time where these observations will be possible. The BOC endorses the continuation of groundwater data collection and analysis for the next few years. The BOC encourages future efforts in this study to focus on anomalies, or specifically areas where precipitation does not seem to cause groundwater changes. From the standpoint of structure performance, it is important to establish if there are any groundwater conditions that could be related to the reservoir level, to flow through the FCO chute, or under the RCC apron.

4. Does the BOC have any recommendations or comments on the 2018/19 Reservoir Operations plan?

Response

The presented Reservoir Operations Plan was developed in coordination with partner agencies with the goal of passing the Standard Project Flood (SPF) outflow of 150,000 cfs while avoiding use of the Emergency Spillway, and with no increase to the exceedance frequency for critical pool elevations and downstream flow thresholds. The Reservoir Operations Plan increases the flood pool storage to reflect the absence of the Marysville Reservoir that was assumed to be in place when the original reservoir operational rules were established in 1970. The BOC concurs with the interim Reservoir Operations Plan as stated in the presentation.

5. Does the BOC have any recommendations or comments on the hydraulics and hydrology update?

Response

The Design Team confirmed the stage-discharge relationships for the ogee and broad-crested sections of the Emergency Spillway for the improved spillway

configuration using textbook methods, three-dimensional computational fluid dynamic modelling (CFD), and a physical model study. CFD modeling was also used to evaluate the flow over the stepped RCC buttress section. Two-dimensional hydraulic modelling was used to determine flow velocities, depths, and shear forces on the stepped RCC apron of the Emergency Spillway. Two-dimensional modelling was also performed to evaluate approach losses to the FCO and Emergency spillways for the lower range of flood flows. The hydraulic analyses completed to date confirm the acceptable performance of the spillway. The BOC recommends that the two-dimensional modelling of the approach losses to the FCO and Emergency spillways also be completed for the PMF flow condition.

6. Does the BOC have any recommendations or comments on the spillway surveillance plan?

Response

A presentation was made on the FCO and Emergency spillways surveillance and monitoring plan that included the following components:

- Frequent visual inspections of the headworks, FCO chute, and emergency spillway, as well as monitoring via mobile video cameras.
- Automated surveys of the headworks and FCO chute walls.
- FCO spillway chute piezometer monitoring and drain outfalls.
- Visual inspection of flows during spills for flow depth, and irregular flow patterns.
- Inspection after spill events and documentation of the condition of chute surface slabs for existing or new cracking and seepage, if any.
- Documenting base line ground water conditions in the vicinity of both spillways, using existing and planned piezometer installation.
- Establishing threshold levels for instrumentation reading, based on design criteria and baseline readings.
- Providing a mechanism and frequency of reporting.

The BOC requests a copy of the Dam Safety Surveillance and Monitoring Plan (DSSMP) that includes the spillway monitoring plan be provided for review.

The BOC notes that the historical activation or use of the FCO spillway has often involved several years between making releases. The BOC recommends that the Spillway Surveillance Plan include a deliberate and monitored annual test release of flow in the FCO spillway, assuming the reservoir condition allows such a release. The test should include a visual inspection of the interior of the spillway before and after the test, and observation of the flow surface during the test.

Also, although not discussed and included as part of this recovery project, if non-linear stability stress analyses are performed to determine the potential for damage to the FCO Headworks during seismic events, and the analyses include collecting actual dynamic structural performance data for the structure to verify the natural frequencies of the computer model, the BOC recommends that the natural frequency information obtained for the structure be included in the Spillway Surveillance Plan for future health monitoring of the FCO Headworks. Dynamic structural vibration monitoring can provide an economical method of detecting structural problems not measured by current instrumentation or observed by visual inspections. With this information, changes in the structural integrity of the FCO Headworks can be assessed periodically and following extreme events such as floods and earthquakes. Changes in natural frequency can serve as an indication of potential structural integrity issues, such as underwater or underground cracks, breakage of post-tensioned anchor(s), and concrete deterioration.

The BOC would also appreciate being kept informed of performance of the FCO during the first discharge, including viewing the video taken during the spill. As small Unmanned Aerial systems or drones (UAS) were an integral tool to monitor repair activities, the BOC recommends that UAS imagery also be integrated into the Spillway Monitoring Plan, especially during flows in the FCO Spillway and over the Emergency Spillway.

7. Does the BOC have any recommendations or comments on FCO surface treatment plan?

Response

The BOC believes the quality of the finished surface of the reinforced concrete slabs within the FCO chute exceeds normal construction standards and that the completed FCO chute has been restored to safe operation. As noted in previous BOC memoranda, the BOC notes that the concrete slabs constructed in 2018 show less shrinkage cracking than those completed in 2017 and commends the Design Team on implementing modifications to the concrete mix design and placement to improve the quality of the concrete.

During the meeting, the Design Team presented several measures under consideration to further enhance and protect the surface of the spillway slabs. Of the measures presented, the only one that the BOC believes has merit is the use of a crystalline-type waterproofing system that chemically controls and permanently creates a non-soluble crystalline structure throughout the capillary voids of the concrete surface. This system causes the concrete to become sealed against the penetration of liquids from any direction, seals hairline cracks, and helps protect the concrete from deterioration. While the BOC considers the current surface condition of the slabs to be satisfactory, the BOC is in favor of using this type of waterproofing system as a protective measure to further improve the robustness and reliability of the spillway chute. The BOC recommends that the Design Team evaluate this relatively new technology and determine if it has merit.

A presentation was given of the cracking pattern that can now be seen developing in the Emergency Spillway RCC apron, which was expected and is typical for RCC armoring for such large areas. It would be of interest to map the crack pattern that finally develops on the RCC apron surface. This might be readily accomplished by drone video in the period of drying after a rainfall.

8. *Does the BOC have any recommendations or comments on the spillway drain video inspection plan?*

Response

The BOC was impressed with the amount of detailed custom design and construction work performed to configure and optimize the drainage systems for the FCO and Emergency spillways. The Contractor has demonstrated a high degree of resourcefulness in field fitting the drain outfalls for the weir monoliths foundation drains and the drain lines along the toe. This required cutting trenches for the drain lines into newly placed RCC lifts and backfilling the installation with conventional concrete. Care should be taken to keep the RCC lift properly moisture conditioned while this operation is being performed.

During the presentations, it was stated that all drain lines that can be accessed will be videoed by remotely operated vehicles equipped with cameras. The BOC fully supports the Design Team's efforts to video document the condition of all drain pipes and recommends that the video records be archived to serve as a baseline for referencing future video inspections.

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

Response

- 1. Additional geologic drilling upstream of Emergency Spillway:** An update on the plan to investigate foundation conditions upstream of Emergency Spillway Monoliths 2 & 3 was presented to the Board. This information was recently summarized in *SRT-ORO-GO-12G - Additional Geologic Exploration*. The Board endorses this plan and notes that the effort is primarily to confirm that the monolith stability for existing subsurface discontinuities is favorable.
- 2. Comment on TMs planned for the geologic investigations:** The BOC was provided a list of Technical Memoranda (TMs) currently being prepared by Project Geologists to document all geologic mapping, field investigations, installed instrumentation, monitoring during construction, documentation of foundation conditions, and any slope stability assessments. The BOC commends the Design Team on this undertaking and considers this effort to be an essential component of the construction documentation for the project. It is the BOC's understanding that the memoranda will be incorporated in a comprehensive "Project Construction Geology Report." Documentation of these investigations and studies should provide a useful resource for any future safety assessments, or for potential studies identified in the Comprehensive Needs Assessment planning study.

CONCLUDING COMMENT

The BOC commends the Design Team for their focused and thoughtful design efforts over the course of this intense and strenuous endeavor under very difficult circumstances and recognizes the contributions and timely review of staff of the FERC and DSOD. The BOC believes the completed project will be robust, reliable and resilient, and will restore the Oroville Dam project to continued safe operation.

BOC RECOMMENDATIONS SUMMARY

M21-1 The BOC recommends that the Design Team review the future construction work associated with the restoration plan to determine if any of the remaining features should be constructed early to make best use of the Contractor's resources before they are demobilized

such as the RCC, conventional concrete, and rock aggregate crushing plants, or other specialized onsite equipment.

- M21-2 The BOC recommends that the two-dimensional modelling of the approach losses to the FCO and Emergency spillways be completed for the PMF flow condition.
- M21-3 The BOC recommends that the Spillway Surveillance Plan include a deliberate and monitored annual test release of flow in the FCO spillway, assuming the reservoir condition allows such a release.
- M21-4 the BOC recommends that the natural frequency information obtained for the structure be included in the Spillway Surveillance Plan for future health monitoring of the FCO Headworks.
- M21-5 The BOC recommends that the Design Team evaluate the new crystalline-type waterproofing system technology to determine if it has merit for the surface of the FCO spillway chute slabs.
- M21-6 The BOC recommends that the video records of the drain pipe inspections be archived to serve as a baseline for referencing future video inspections.

Respectfully submitted,



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