

Lake Oroville Spillways Emergency Recovery

Board of Consultants Memorandum No. 10 – July 25, 2017

Prepared by the California Department of Water Resources

Summary & Response

Discussion and comments on presentation to the Board of Consultants (BOC)

These initial paragraphs summarize a variety of topics presented to the BOC. The first few paragraphs relate to similar discussions from BOC #9. As outlined in the BOC #9 summary, the lower chute will be constructed with roller compacted concrete. The first four paragraphs cover the construction details associated with construction techniques of the RCC.

The cavitation potential investigations were also previously covered in BOC #9 and the summary. The BOC is providing recommendations for consideration of construction details of the RCC to mitigate for the potential of cavitation.

The construction progress and schedule section outlines the discussion regarding construction progress and schedule. This presentation was a result of a request by the BOC during BOC meeting #9.

Question 1

Points 1, 2, 3 and 4 continue from BOC #9 and relate to the details associated with the construction of the RCC in the lower part of the chute.

Point 5 relates to the repair or reconstruction of the dentate structure. The dentate structure refers to the very large blocks at the very end of the spillway which provide dissipation of the water just before entering the river.

Point 7 relates to the initial placement of RCC in the smaller crevices and canyons.

Question 2

Question 2 relates to the techniques associated with cleaning the foundation. Rock foundation for dams and its appurtenant structures are typically cleaned which could include washing and sometimes vacuuming the rock to allow adhesion between the rock and newly placed RCC or concrete.

Question 3

Question 3 relates to the construction schedule and follows the request made by the BOC to keep them informed of progress and schedule.

The topic of the secant wall relates to the wall that is being placed downstream of the emergency spillway. There are currently scheduling conflicts between the construction of the secant wall and



relocation of overhead transmission lines. This has been brought up to the BOC since this could possibly delay the completion of the secant wall by a couple months.

Question 4

Point 2 of question 4 relates to instrumentation that has been placed within the foundation beneath the FCO chute. Piezometers are instruments that allow engineers to measure water pressures that could possibly occur beneath the chute within the rock foundation.



OROVILLE EMERGENCY RECOVERY – SPILLWAYS

Board of Consultants Memorandum

DATE: July 25, 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. 10

INTRODUCTION

On Monday, July 24, 2017, the Independent Board of Consultants (BOC) met at the DWR Oroville Field Division Main Conference Room office at 9:30 am. Representatives from DWR Engineering Division, DSOD, FERC, and industry consultants working on the Oroville Spillway Recovery project participated in the meeting.

Presentations were made by DWR and their consultants on both design and construction progress. The meeting began with a brief presentation on the timeline of key design milestones that have been accomplished since the initial FCO Spillway and Emergency Spillway erosion incidents occurred approximately five months ago.

Milestones included:

- Organizing design teams.
- Performing an alternatives analysis.
- Preparing 30 percent designs.
- Advertising the construction contract.
- Awarding the construction contract.
- Mobilizing equipment and plants.
- Procuring construction materials.
- Preparing final plans and specifications.
- Proceeding with major construction activities.

Presentations were made on the progress of the RCC foundation construction for the FCO Spillway, provisional RCC transition details for the FCO Spillway chute, the sensitivity of the hydraulic performance of the FCO Spillway chute to the surface roughness of the exposed concrete and RCC, and an update on the FCO Spillway foundation conditions and foundation preparation.

Later in the afternoon, the meeting was moved to the Contractor's field office at the dam site for a presentation by the Contractor's representatives on construction progress. Following this, the meeting was moved to the DWR onsite construction trailer for an update on the construction of the Emergency Spillway secant pile cutoff wall. Descriptions and comments made on the individual presentations are contained in the section that follows.

The BOC returned to the dam site at 8:00 pm after having dinner to observe RCC placement within the scour hole adjacent to the foundation of the FCO Spillway chute, and departed around 9:30 pm.

During the morning of Tuesday, July 25, the BOC toured the dam site to observe construction progress. This included the following:

- An overlook at the gate structure of the FCO Spillway.
- A review of the remaining demolition work near Station 20+30 of the FCO Spillway.
- An inspection of the FCO Spillway chute rock foundation that is currently being cleaned from approximate Stations 23+00 to 27+00.
- An overlook of the spillway chute leveling concrete placement near Station 37+00.
- An overlook of the RCC placement on the left side of the FCO Spillway near Station 36+00.
- An inspection of the reinforced-concrete test slab for the FCO Spillway.
- An inspection of the drilling for the Emergency Spillway secant pile cutoff wall.

The BOC then returned to the DWR Oroville Field Division Office Main Conference Room to deliberate and prepare the report. This was followed by a reading of the BOC's draft report with representatives from DWR Engineering Division, DSOD, FERC, and industry consultants working on the Oroville Spillway. The meeting was adjourned at 4:30 pm.

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

DISCUSSION AND COMMENTS ON PRESENTATIONS TO THE BOC

Design Details for the 1,109-foot-long Provisional Section of the FCO Spillway

Chute between Stations 28+20 and 39+29 - At our previous meeting, the BOC was informed that the RCC in this area will be overlain with a 1-foot-thick layer of higher strength RCC with a mix design containing 300 pounds per cubic yard (pcy) of Portland cement and 175 pcy of fly ash. The original RCC foundation has a mix design with 175 pcy of Portland cement and 175 pcy of fly ash (2,500 psi and 4,000 psi compressive strength after 28 days and 1-year, respectively). The top layer of RCC is designed to have a 14-day strength of 3,000 psi. A surface hardener treatment is being evaluated that is reported to increase the strength of the RCC chute surface to about 8,000 psi.

At Station 28+20 where the new reinforced-concrete FCO Spillway transitions to the provisional RCC chute, the transition detail consists of a temporary 15-foot-long section of reinforced-concrete slab and downstream cutoff wall that is anchored to the bedrock foundation. The downstream cutoff wall has a minimum depth of 8 feet and is also anchored to the bedrock foundation. When the RCC foundation material and the 1-foot-thick layer of higher strength RCC overlay are placed against the reinforced concrete cutoff wall, a 3-foot vertical step will result that can be used to aerate spillway flows.

The lower transition detail at Station 39+27 is similar and consists of a zone of high strength RCC placed against a temporary 1V:1H tapered reinforced-concrete cutoff wall and slab section anchored to bedrock. The zone of high strength RCC will be placed approximately two inches higher than the top of the downstream reinforced-concrete chute slab to avoid the possibility of stagnation pressures from developing at the RCC – reinforced-concrete interface.

The temporary spillway training walls will be constructed using horizontal lifts of RCC placed concurrent with the horizontal lifts of the RCC foundation. The vertical inside faces of the wall will be formed using a Hilfiker welded wire wall forming system, and later surfaced with a 6-inch thick application of 7,000 psi shotcrete reinforced with steel fibers. The finished exposed inside height of the temporary RCC training walls will be 15 feet.

RCC Placement Progress - It was reported that RCC placement began on Thursday, July 20, and is progressing well with no adverse issues related to placement temperatures. Adjustments are being made to address surface bleed water and occasional Vee-Bee time exceedances that have been traced to moisture variations in the fine aggregate stockpile. Modified RCC side slope compaction equipment was reported to be working very well. RCC surface cleaning equipment and techniques are being refined.

Cavitation Potential Investigations - The sensitivity analysis of the roughness of exposed concrete and RCC surfaces within the FCO Spillway chute was conducted using a computational approach developed by the Bureau of Reclamation. The numerical analysis consists of varying the Manning's "n" value for the spillway chute from 0.014 to 0.023. The sensitivity analysis showed that the roughness of the finished chute surface has a significant impact on the spillway hydraulics and the potential for cavitation damage within the chute. For the higher Manning's n value of 0.023, the computed cavitation index along the profile of the spillway chute for a uniform flow of 100,000 cfs was shown to be above the critical cavitation index value of 0.20, suggesting that the potential for cavitation damage for this scenario would be minimal. For lower Manning's n values, the cavitation index was less than 0.20 downstream of Station 32+00 suggesting that there would be potential for cavitation damage to the spillway chute if the flow is not aerated. Water surface profiles computed using the higher surface roughness were determined to be acceptable for the provisional RCC spillway chute section. Various configurations of air vents in the transition wall at Station 28+20 that are being considered by the Design Team were also presented.

Spillway Foundation Preparation - The update on the FCO Spillway foundation conditions and foundation preparation included a virtual tour of the FCO Spillway chute using drone imagery. Foundation shear zones, foundation cleaning, placement of dental and leveling concrete, erection of transverse drain forms, chute anchor installation, instrumentation, drain pipes, RCC placement, remaining drilling and blasting demolition work and other features were shown and discussed. Information on the July 19, 2017 small slide located at the right side of the FCO Spillway "arena" cut near Station 28+50 was presented and discussed. Foundation mapping, cleaning, and acceptance procedures were presented.

Construction Progress and Schedule - The presentation by the Contractor's representatives focused on construction progress, revised schedule milestones, expected production rates, planned construction schedule, tools being used to track daily progress, manpower loading (including subcontractors), daily quantity tracking, critical path items and problems that have been encountered and how they have been addressed. The Contractor is focused on completing the required work within the remaining 100 days until the November 1, 2017 deadline, and presented details on how they plan to complete the work. The Contractor currently has approximately 120 full-time staff and 450 craftsmen onsite. Detailed commodity curves, initial production rates and material supply issues were presented and discussed.

Because of higher than anticipated waste from the processing of excavated onsite material for coarse and fine RCC aggregates, the production rates of these materials was determined to be insufficient to meet required RCC production rates. The

Contractor is therefore mobilizing a second onsite plant to manufacture RCC aggregates. The Contractor also noted that the available stockpiled material may not be adequate to provide the needed quantity of RCC aggregate, and that there may be a need to identify alternate sources of rock to process to manufacture RCC aggregate. The Contractor also summarized information concerning onsite conditions and final design features that have impacted the original construction schedule. Quantities for critical contract items have been updated to reflect current actual conditions. Key items included the increase in excavation for the FCO chute from 97,000 CY to 347,000 CY (357% increase), the increase in slab anchors from 37,400 LF to 113,120 LF (302% increase), the increase in RCC from 242,000 CY to 300,000 CY (20% increase), etc. Progress and challenges for individual critical path work items was presented and discussed. The BOC is confident that the Contractor's scheduling and forecasting system allows for easy understanding and accurate tracking of construction progress.

Secant Pile Cutoff Wall - The update on the construction of the Emergency Spillway secant pile cutoff wall noted that the majority of the leveling pad and starter wall has been constructed and the secant pile wall construction equipment has been mobilized to the site. A total of 605 secant piles will be drilled and installed to construct approximately 121 individual panels of 5 piles each (piles in each panel are designated as A, B, C, D & E). The Contractor's sequence for completing both the Primary Piles and Secondary Piles in three panel groups was detailed. The first test panel has been partially constructed. The Contractor used a single BG-40 rotary drill for work to date. A second drill, a BG-50 drill using a down-hole hammer and button bits for drilling the harder less weathered rock is scheduled to commence drilling this week. The documentation and geologic logging of the secant pile walls was presented and discussed. Ground-water was present at approximately 30 feet in most holes drilled to date. The Design Team added 7 piezometers in the area for monitoring. The reservoir is currently at Elevation 801 feet. Complications with construction of the secant pile wall due to restrictions under the powerline were also presented and discussed.

QUESTIONS FOR THE BOC

1. Does the BOC have any recommendations or comments on the design concepts and details for the FCO Spillway Chute between Station 28+20 and Station 39+30?

Response

The BOC compliments the Design Team and the Contractor for the highly responsive way they are creatively and effectively addressing problems as they are encountered. The design concepts and details for the FCO Spillway chute between Station 28+20 to Station 39+30 represent unique challenges for constructing a provisional segment of the spillway chute that will perform satisfactorily for the seasonal wet period following the 2017 construction season. The BOC is in agreement with the proposed design concepts and details, and offers the following comments and recommendations.

1. The BOC encourages the Design Team to continue to work towards including an aerator at Station 28+20. The proposed 3-foot stepped transition provides a unique opportunity to include an aerator at the upstream end of the provisional RCC section of the chute. The BOC continues to believe that this would be a highly effective measure to protect the RCC surfaces exposed to high velocity flows.
2. The BOC is interested in the details of the Sika surface hardener and how it will be used for this spillway. The BOC recommends that the application of the surface hardener be demonstrated on the proposed supplemental RCC trial section. The BOC also recommends that the Design Team consider selective use of the Sika surface hardener, and reserve its application to zones of high impact such as where the flow impinges on the chute downstream of the transition step at Station 28+20. As described in the discussion section above, the BOC is concerned that the application of the surface hardener may create an unusually smooth uniform surface that would result in higher flow velocities and increase the potential for cavitation and scour damage. The sensitivity analyses performed by the Design Team show that having a uniform but rough RCC surface could be beneficial by lowering flow velocities and thereby reducing the potential for cavitation and erosion damage.
3. The BOC recommends that the Design Team evaluate steepening the slope of the outside RCC foundation face near Station 28+50 to avoid placing RCC in the area of interference with the hillside landslide that is located at the right side of the FCO Spillway. This might require forming a portion of the RCC face.

4. The BOC recommends that a physical model study of the proposed interim spillway configuration be performed to evaluate the transition details and the aerator, if it is included in the design.
5. The BOC understands that the dentate structure is scheduled to have the surficial damage repaired during the 2018 construction season. This repair will require careful concrete removal in order to prevent damaging the existing embedded reinforcement as little as possible, and then dowelling in the new concrete to restore the original dentate configuration. It was stated that the Contractor has suggested that completely demolishing the dentate structure and reconstructing a new structure could save money because easier construction would be facilitated. The BOC would encourage further investigation of this option if restoring the dentate structure really needs to be done at this time.

In actual fact, the dentate structure has performed exactly as it was designed. Some erosion of dentate surfaces can normally be expected over the lifespan of such structures. The Oroville Spillway dentate structure was exposed to an exceptional condition being battered by large sections of concrete in high velocity flow, but appears capable of still serving its function for years. The BOC believes the option of leaving its replacement or reconditioning to a future date might be considered.

6. The Design Team has suggested that the Contractor [REDACTED]
[REDACTED]
[REDACTED]
[REDACTED] The BOC agrees that this would be a useful provision. It is also noted that the hydro-blasting anticipated for concrete removal for construction of the dentate structure restoration would prove useful for removal of the temporary RCC portions of the chute from Station 28+20 to Station 39+30.
7. The BOC was pleased to see that the lower scour hole had been cleared of the material that had been cleaned out of the “Hell Canyon” feature in the chute and dozed into that area. The initial placements of RCC had already risen high enough to provide a clear area for equipment to work more expeditiously. During the night visit to observe RCC placement, the BOC was able to witness placement and compaction of an RCC lift. The Contractor’s adaptation of several pieces of mechanical equipment to spread and compact the RCC in small corners and recesses was particularly appreciated as beneficial innovations to speed up the RCC operation. Overall, the BOC believes the RCC operation is off to a good start.

2. Does the BOC have any recommendations or comments on the foundation conditions and preparation?

Response

- 1. *Cleaning of the FCO Spillway Foundation.*** The BOC is impressed with the progress and quality of the foundation cleaning. The cleaning of areas of the chute foundation for placement of RCC and leveling concrete that were observed by the BOC exceed expectations and represent significant progress. The BOC visited an area of the spillway chute rock foundation that was being cleaned from approximate Stations 23+00 to 27+00 (see photographs in Figure 1). This rock surface is rough and all soil material has been removed by cleaning. This differs from the original chute foundation design that allowed some soil to remain under the original leveling concrete. The thickness of leveling concrete appeared to typically range from 3 to 6 feet in thickness, but in local areas where fractured or more weathered material was removed, the leveling concrete thickness may exceed 10 feet. At this location the BOC also observed the Stay-Forms that are being used to create the drains that extend through the leveling concrete to the rock foundation surface (see Figure 1).



Figure 1. Photographs of typical FCO foundation preparation showing foundation cleanup and Stay-Form (upper photos), and placement of leveling concrete (lower photo).

3. Does the BOC have any recommendations or comments on the construction schedule?

Response

1. The BOC was pleased with the progress made since the last onsite meeting. It is clear that the Design Team and the Contractor are effectively communicating with each other and are fully aware of the urgency of the project. They appear to be working well together and cooperating to accomplish this deadline-driven project. Initial work items such as the demolition of sections of the FCO Spillway and foundation preparation have been very well executed. It is apparent that the Design Team and the Contractor's investments in planning and preparation for critical path construction work is paying off and resulting in an efficient and productive execution of the work. The amount of work completed since the spillway erosion incident occurred just five months ago is impressive.
2. On the basis of the Contactor's presentation, The BOC understands that progress on the secant pile construction has been impacted by the rate of drilling of currently used drilling equipment, and expected constraints of working in the vicinity of the overhead transmission towers. The currently projected completion date for this task is late December or early January, 2018. The BOC understands that the Contractor has already brought a heavy duty percussion drilling rig to improve on the current rate of drilling. The BOC recommends that measures be explored for relocating the transmission towers in a timely manner to minimize their impact on the completion of the secant pile construction.
3. The BOC would appreciate receiving weekly information on construction progress and schedule updates similar to those shown by the Contractor during their July 24, 2017 presentation to the BOC.

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

Response

1. The BOC compliments the Design Team on their organization of the information presented during the meeting and the quality of the presentations. A significant amount of information on a wide range of topics covering many disciplines was clearly presented, and is appreciated by the BOC.
2. The BOC understands that a number of vibrating wire piezometers have been installed (at 7 locations) beneath the reinforced concrete slab in the upper FCO Spillway chute between Stations 14+00 and 28+00. These piezometers should provide useful information on the ground-water conditions beneath the chute.

The BOC recommends that these piezometers be monitored on a regular basis to provide a baseline for comparing the performance of the existing chute slab to that of the replacement structure completed in 2018, particularly at high reservoir levels.

3. The BOC visited the Emergency Spillway secant wall installation where the smaller of the Contractor's two drills is being used to drill through the intensely and moderately weathered rock. The hardness of the rock results in low drilling rates and significant wear on the drill teeth. Once the percussion drill begins operation in the lower portion of the holes that are in the slightly weathered amphibolite, a better understanding of the effective drilling rate can be determined. The BOC awaits ramp-up to full production.
4. The BOC understands that piezometers are currently being installed upstream and downstream of the secant pile wall to help monitor ground-water levels and verify that the designed separation between the pile panels is providing the intended drainage to prevent buildup of pore pressure under the RCC buttresses, scheduled to be installed in 2018 construction season. The BOC concurs with these measures.
5. Before demolishing the reinforced-concrete FCO Spillway test slab, the BOC suggests that the Design Team consider taking core samples to obtain data on the bond between the slab and the leveling concrete.

BOC Recommendations Summary

- M10-1 The BOC encourages the Design Team to continue to work towards including an aerator at Station 28+20. The BOC continues to believe that this would be a highly effective measure to protect the RCC surfaces exposed to high velocity flows.
- M10-2 The BOC recommends that the application of the RCC surface hardener be demonstrated on the proposed supplemental RCC trial section.
- M10-3 The BOC recommends that the Design Team consider selective use of the Sika surface hardener, and reserve its application to zones of high impact such as where the flow impinges on the chute downstream of the transition step at Station 28+20.
- M10-4 The BOC recommends that the Design Team evaluate steepening the slope of the outside RCC foundation face near Station 28+50 to avoid placing RCC in the area of interference with the hillside landslide that is located at the right side of the FCO Spillway.
- M10-5 The BOC recommends that a physical model study of the proposed interim spillway configuration be performed to evaluate the transition details and the aerator, if it is included in the design.
- M10-6 The BOC encourages further investigation of the dentate removal and reconstruction option if restoring the dentate structure really needs to be done at this time. The BOC believes the option of leaving its replacement or reconditioning to a future date might be considered.
- M10-7 The BOC recommends that measures be explored for relocating the transmission towers in a timely manner to minimize their impact on the completion of the secant pile construction.
- M10-8 The BOC would appreciate receiving weekly information on construction progress and schedule updates similar to those shown by the Contractor during their July 24, 2017 presentation to the BOC.
- M10-9 The BOC recommends that the piezometers being installed in the existing upper spillway chute slab be monitored on a regular basis to provide a baseline for comparing the performance of the existing chute slab to that of the replacement structure completed in 2018, particularly at high reservoir levels.

- M10-10 The BOC suggests that the Design Team consider taking core samples of the reinforced-concrete FCO Spillway test slab before it is demolished to obtain data on the bond between the slab and the leveling concrete.
- M10-11 Once the secant percussion BF-50 drill begins operations, the BOC would appreciate an interim-meeting update on the drilling rates in the slightly weathered amphibolitic rock.

Respectfully submitted,



Eric B. Kollgaard



Faiz Makdisi



Kerry Cato



John Egbert



Paul Schweiger

relocation of overhead transmission lines. This has been brought up to the BOC since this could possibly delay the completion of the secant wall by a couple months.

Question 4

Point 2 of question 4 relates to instrumentation that has been placed within the foundation beneath the FCO chute. Piezometers are instruments that allow engineers to measure water pressures that could possibly occur beneath the chute within the rock foundation.

