Lake Oroville Spillways Emergency Recovery

Board of Consultants Memorandum No. 11 – August 25, 2017

Prepared by the Department of Water Resources

Summary & Response

Introduction of Board of Consultants (BOC)

The BOC met on August 24 and 25 to observe construction progress on the various components of the spillways recovery. The meeting included a field inspection and a series of presentations from DWR staff and consultants to the BOC.

Question 1

Question 1 relates to the construction schedule. The contractor and DWR are working towards a schedule to complete construction on various components of the project by November 1, 2017. The BOC notes various issues and their associated coarse corrections necessary to keep to the schedule. The details described such as fly ash and concrete aggregate are components of the concrete that is being used to construct the spillway. The BOC also references the placement rate of RCC. During the beginning of RCC projects, there is very little area to work. As the RCC is placed, the surface area of placement increases and then the rate of placement increases. The BOC notes the RCC placement rate is expected to increase.

During major construction projects, issues typically arise that need to be resolved. The BOC compliments the Design Team and the Contractor for aggressively addressing the production problems that are encountered.

Question 2

Question 2 relates to the conventional and structural concrete being used for the spillway. There are generally two concrete mix designs being used in this project. Roller compacted concrete (RCC) is currently being used to fill the large erosion areas that were created by the incident. Conventional or structural concrete is used along with steel reinforcement for components such as the slabs and walls of the new spillway. The BOC notes flange beams are used within the walls. This is part of the construction process of building the walls.

Question 3

Question 3 relates to foundation preparation. Prior to placing any concrete, the foundation receiving concrete needs to be prepared. This preparation includes excavating to acceptable rock and cleaning the rock so there is bond between the concrete and foundation. The BOC notes the foundation preparation work exceeds their expectations.

Question 4

Question 4 relates to the RCC and the tests being completed to check the strength and resistance to flow of the RCC. The final layer of RCC will be placed on a slope versus placing it in horizontal lifts. This final lift will be stronger and be more resistant to the spillway flows. The RCC within parts of the lower chute could potentially be relied upon during this winter. Structural concrete will be placed over the RCC during the next construction season. Therefore parts of the RCC will be removed during next construction season to receive the future structural concrete.

Question 5

Question 5 relates to the secant wall which will be constructed downstream of the emergency spillway. This will ultimately be an underground wall the length of the emergency spillway. The BOC notes the construction of the secant wall is behind schedule. The BOC is recommending the length of wall near where most of the damage occurred (headcutting) be constructed as a priority if the entire length does not get finished within the prescribed schedule.

Question 6

Question 6 relates to instrumentation in and around the construction site. Piezometers are used to understand the water level beneath the ground. Slope indicates are used to understand if there is any movement of the slopes in and around the construction site. The BOC concludes that groundwater levels in and around the spillway are not directly affected by the reservoir. They also conclude any movement of the sloping ground is not significant.

Question 7

Question 7 relates to hydraulic models being used to calculate expected flow conditions for the new spillway. The physical model is a scaled model constructed in Utah. The numerical model refers to mathematical models. Both types of models are used to predict how the spillway will perform with respect to water flowing down the spillway. The BOC commends DWR for the in-depth modeling that is being performed.

Question 8

Question 8 relates to the schedule and is self-explanatory.

Question 9

Question 9 relates to the vegetation that has periodically been seen on the face of the dam even before the dam was complete. The BOC completed an independent assessment of the vegetation that is on the downstream slope of the dam. The BOC notes the team's assessment was thorough. The BOC concluded the source of water that affects the vegetation is not related to seepage originating from the reservoir and is not a dam safety concern.

Question 10

Self-explanatory.

OROVILLE EMERGENCY RECOVERY – SPILLWAYS
Board of Consultants Memorandum

DATE: August 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. 11

INTRODUCTION

On Thursday August 24, 2017, the Independent Board of Consultants (BOC) met at the Department of Water Resources (DWR) Oroville Project Site Office, Trailer No. 12 at 8:00 am. Representatives from DWR Engineering Division, California Division of Safety of Dams (DSOD), Federal Energy Regulatory Commission (FERC), the Contractor, the U.S. Army Corps of Engineers (USACE), and industry consultants working on the Oroville Spillway Recovery project participated in the meeting.

Presentations were made by DWR, their consultants, and the Contractor on design and construction progress. Presentations were made on the progress of the roller-compacted concrete (RCC) foundation construction for the Flood Control Outlet (FCO) Spillway, the provisional RCC transition details for the FCO Spillway chute, an update on the construction of the Emergency Spillway secant pile cutoff wall, and the hydraulic analyses for the FCO and Emergency spillways. Descriptions and comments made on the individual presentations are contained in the section that follows.

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

- an inspection of the remaining exposed FCO Spillway chute rock foundation cleaning;
- a review of the upstream spillway chute transition from the old spillway to the new spillway near Station 20+30;
- the RCC and structural concrete placement within the FCO Spillway;

- the construction of temporary RCC gravity spillway training walls;
- erection of the steel reinforcement and forms for initial segments of the permanent FCO Spillway training walls;
- an inspection of the high strength RCC test slab placed on a 4H:1V slope;
- an overview of the vegetated area ("green spot") on the downstream embankment slope; and
- an inspection of the drilling and construction for the Emergency Spillway secant pile cutoff wall.

The BOC then proceeded to the DWR Oroville Project Site Office, Trailer No. 13 at 10:30 am for a presentation by the Design Team regarding their comprehensive investigation of the vegetation area. The presentation included the design features and construction history of the dam embankment with an emphasis on the performance of the dam since it was put into service 50 years ago, and on the causes of the vegetation observed on the downstream slope at various locations. The BOC then met 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 working on the Oroville Spillway at 4:00 pm. The meeting was adjourned at 4:30 pm.

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 schedule?**

   Response

   1. The Contractor and the design team are aggressively monitoring the construction schedule and critical path work items. Some work items have been impacted due to lower than targeted production rates which were explained by the design team and Contractor, and which are related to cement and fly ash delivery problems, conventional concrete aggregate supply issues, and low initial placement rates for the RCC associated with working in small areas within the foundation and the addition of RCC walls in the middle section of the FCO chute. The Contractor has addressed these problems by leasing more trailers to expedite delivery of cement materials, locating new concrete aggregate suppliers, and increasing the number of

work crews. The RCC placement rate is expected to increase due to having more and larger work areas. The Contractor has effectively shown that RCC placement production has increased as the placement area increases beyond the narrow rock crevasses. In addition, the Contractor's learning curve has been steep, but he has shown innovation and dedication to quality. This has included staff training, familiarity with project specifications, and managing site-specific conditions. The Contractor and Design Team are confident that production rates will continue to improve over the remaining 68 days to meet the November 1 deadline. The Contractor currently has approximately 122 full-time staff and 549 craftsmen onsite. The BOC compliments the Design Team and the Contractor for aggressively addressing production problems as they are encountered and for developing a thoughtful plan to stay on schedule. During the tour of the construction site on Friday August 25, the BOC was impressed with the organization and execution of the construction work being performed and is optimistic that the project will be completed as planned.

2. RCC aggregate production is a concern, not for the construction of the FCO spillway but for the construction of the RCC apron for the Emergency Spillway. Actual waste material from the aggregate production is approximately 50 percent as opposed to the 20 percent assumed in the Contractor's projections. In response, the Contractor has set up a second aggregate manufacturing plant, and is investigating additional onsite sources of rock to process. Offsite material sources are also being considered.

3. Despite some items being behind schedule, the BOC notes that the work being performed is of high quality and in compliance with the specifications. The BOC is pleased with the quality control, quality assurance and worker safety programs for this project.

4. The one schedule item of note is with the secant cutoff wall installation due to the subcontractor's lower than anticipated production rate. The lower production rate has been due to equipment problems, equipment being slow to arrive on site, and variable subsurface rock conditions. The BOC endorses the Design Team's modifications to this work and believes the changes to the specifications recognize actual rock conditions, and will not adversely affect the quality of the finished cutoff wall.

2. Does the BOC have any recommendations or comments on the conventional and/or structural concrete design and placement?

Response

1. The Contractor's use of vertical wide flange beams (WFBs) within the FCO spillway training walls is viewed by the BOC as a positive feature and a bonus for the project. Consolidation of the concrete around WFBs within the walls, however, may be a challenge and should be monitored carefully.

2. The BOC agrees with the Design Team's rationale for adding anchors to, and reducing the depth of, the cutoff wall for the broad-crested weir control section ("speed bump") of the Emergency Spillway based on the higher quality bedrock encountered in this area.

3. Does the BOC have any recommendations or comments on the foundation prep and construction?

Response

1. The cleaning of the chute foundation areas for placement of RCC and leveling concrete is almost complete. All of the foundation preparation work completed to date continues to exceed the BOC's expectations. The foundation preparation for the new FCO spillway is of the highest quality and is an important accomplishment for the success of the project.

2. During placement and consolidation of the drain fill material over the slotted drain pipe, some fine-grained material entered the drain pipe through the drain slots. Although the amount of the fine-grained material is minor and does not impact the hydraulic capacity of the drainage system, the BOC recommends that the drain pipes be cleaned and video inspected at the conclusion of construction to establish a neat baseline for future inspections.

4. Does the BOC have any recommendations or comments on the RCC design and placement?

Response

1. The BOC recommends that consideration be given to reducing the thickness of the final lift of RCC if it is determined that the 12-inch thickness becomes too difficult to compact. The extra time required for additional passes of the roller compactors could adversely impact the Contractor's completion schedule.

2. The BOC looks forward to learning the outcome of the hydraulic erosion tests scheduled to be performed on the 4H:1V RCC test section to assess the benefits of using a surface hardener on the grout enriched RCC lift. When these tests are performed, they should test the treated and untreated areas for comparison.

3. The vertical inside faces of the provisional RCC spillway training walls are being formed using a Hilfiker welded wire wall forming system, and will later be surfaced with a 6-inch-thick application of 7,000 psi shotcrete reinforced with steel fibers. Some concerns were expressed with the embedment of the No. 4 transverse anchor bars that will be used to anchor the shotcrete steel reinforcement to the vertical face of the RCC gravity wall. Some of the No. 4 anchor bars embedded in the RCC could easily be twisted after the RCC had set. The BOC recommends that steel plates like those shown in Figure 1 be added to the ends of the transvers anchors, or that the ends of the anchors be bent 90 degrees to increase their pull-out resistance.

Figure 1. Example of anchor rods embedded in RCC equipped with steel plates.

4. The BOC was pleased that the RCC test fill on the 4H to:1V slope surface demonstrated the ability of the Contractor's equipment to effectively place and compact RCC on this slope. The RCC had a relatively uniform smooth surface generally free of rough patches and rock pockets. Some minor rutting and tire tracks were observed, but it is anticipated that using the plate compactor on the production placement will eliminate these in the final RCC chute surface. The concrete surface hardener was tested on a number of areas of the test fill and these will be subjected to the hydraulic testing described previously.

5. The BOC recommends that blasting not be used in removing the provisional RCC spillway training walls where such demolition is close to any structural concrete slabs or walls. It was noted that the Contractor has made provisions to use wire cutting to separate the walls from the base slab and to cut the wall into segments. These segments could be reduced to manageable pieces by light charges or the use of a hoe ram.

6. The BOC understands that the Contractor will remove one half of the original RCC test fill by blasting, and the other half using a hydraulic hammer. This will be a trial demonstration in preparation for the eventual removal of the provisional RCC gravity walls in the FCO chute in 2018. As previously noted, the BOC recommends that blasting not be used in close proximity to any permanent work.

7. The BOC understands that chute under-drainage is intended to be used in the portion of the chute structural slabs that are placed on RCC in 2018. Consideration could be given to reducing the diameter of these drain pipes thereby allowing for smaller trench cuts into the RCC.

5. Does the BOC have any recommendations or comments on the secant pile wall construction?

Response

1. If the desired production rates are not achieved and the construction schedule and deadlines become a concern, the BOC recommends that the Contractor focus his resources on completing the sections of the cutoff wall at the two areas where the flow is anticipated to be concentrated and the headcutting is of greatest concern.

2.e The BOC agrees with the Design Team's proposed revised criteria fore determining the point when the secant pile drilling depth has met thee requirement for 15-foot penetration into fresh or slightly weathered bedrock.e

6. Does the BOC have any recommendations or comments on instrumentation?

Response

1.e *Emergency Spillway*: Based on information from secant pile borings ande groundwater piezometers that are located upstream and downstream of thee secant pile cutoff axis, the groundwater depths and flow directions have beene determined. These observations indicate that groundwater is not directlye responding to the reservoir level.e

2.e *FCO Spillway:* Several piezometers have been installed in the FCO spillwaye chute. They are designed to record water that could infiltrate through thee concrete slab floor and deeper flow that could come from the bedrock. Fore instruments that have been installed underneath the new concrete slabs, datae can be obtained in real time, even while spillway flow is occurring.e

Several inclinometers that have been previously discussed, existe[redacted] A few small slope movements have been documented, that required minor slope re-grading, but to date, no significant slope movements have occurred.

3.e *Artificial fill area:* In the artificial fill area that is located about 500 to 1,000 feete left of the FCO spillway chute dentates and near the RCC plant, some slopee movement has been observed. It is believed the observed downslopee movement (toward the river) is contained within or along the base of ae hillslope that is made up of artificial fill that was placed in this location at thee time the dam was constructed. Inclinometers installed within the slope showe that cumulative movement to date, is on the order of almost ½-inch. Thise amount of movement is not alarming, but it will continue to be monitored ase some aggregate stockpiles exist on the overlying slope.e

4.e The BOC believes the instrumentation in both the Emergency Spillway ande FCO Spillway and in the artificial fill area is appropriate and adequate. DWRe has been proactive with instrument installations and the BOC feels thise approach is prudent.e

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

Response

1. The numerical and physical hydraulic modelling for the FCO Spillway and thee Emergency Spillway are critical to the success of the provisional and final spillway features and have provided important design information. The BOC commends the Design Team for the extent and level of detail of the hydraulic analyses being performed for this project. The BOC encourages the Design Team to continue to evaluate and confirm key features of both spillways using these design tools.

2.e On July 31, 2017, Paul Schweiger, on behalf of the BOC, visited the Utahe State University's Water Research Laboratory to observe the operation of thee physical model of the FCO Spillway. The model study is being conductede under the direction of Dr. Michael Johnson. During the visit, Dr. Johnson ande his assistants operated the model for full-scale flows representing 10,000,e 20,000, 50,000, 100,000, 150,000 and 270,000 cfs. The version of the modele observed included an aerated 30-inch vertical step at Sta. [redacted], and two aire slots further downstream of the chutee[redacted]. Observations from the physical model corroborate the numerical computations and design recommendations of the Design Team. The following main observations were made:

   a.e The two aerators downstream of Sta. [redacted] appear to be excessivelye large and create considerable flow disturbance within the FCOe Spillway chute, especially at lower flows. The benefit provided bye these additional aerators is questionable.e

   b.e When the 30-inch step at Sta. [redacted] is aerated [redacted] it appears to perform very well as an aerator for the full range of flows up to the maximum design flow. At the maximum design flow, the amount of air supplied to the step could be increased to improve the aeration for this extreme flow condition, however it still appears to work satisfactorily as an aerator. Increasing the size of the air vents as currently proposed by the Design Team is recommended.

   c. [redacted]

[redacted] The BOC is in agreement with the Design Team's decision [redacted]

3.e The BOC agrees with the Design Team's decision to include an aerator at thee transition step near Statione [redacted] and encourages the Design Team to proceed with a similar design fore the permanent spillway configuration.e

4.e The BOC agrees with the Design Team's revised configuration for buttressinge the Ogee section of the Emergency Spillway with RCC. The BOC suggestse that the Design Team consider using small steps to transition the new RCCe buttress to the conventional concrete Ogee section rather than using ae smooth inclined transition as currently proposed. Constructing the first stepe would require making a longitudinal saw cut along the existing Ogee section.e

8. Does the BOC have any recommendations or comments on the additional work?

Response

1.e The BOC is in agreement with the Contractor proceeding with construction ofe the RCC apron downstream of the broad-crested weir section ("speed bump")e of the Emergency Spillway. This work would commence after completion ofe the RCC in the FCO chute in 2017 and will allow the Contractor uninterruptede placement of RCC using crews and equipment already on site. This is ane important consideration in assuring that the Contractor can complete alle construction during the 2018 construction season.e

2.e The BOC awaits the results of the stability analysis and final configuration ande design of the Emergency Spillway buttressed Ogee monoliths, the details ofe the excavation plan for the downstream RCC blanket, and the drainagee details under the RCC blanket.e

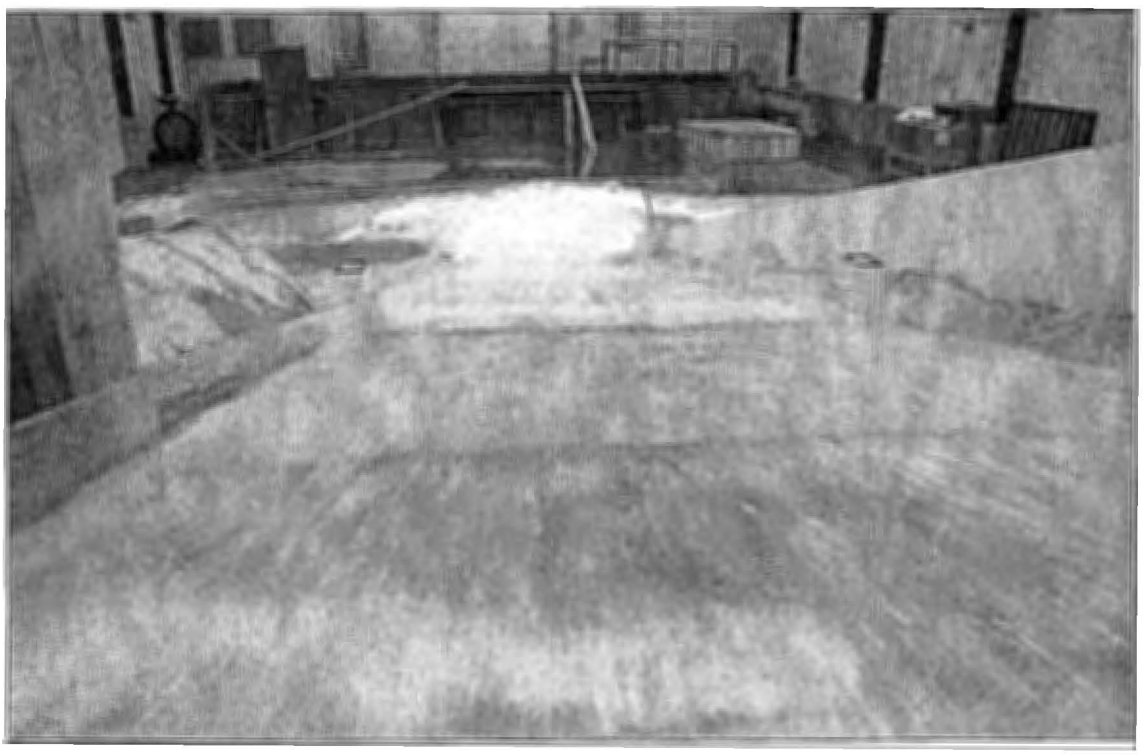

Figure 2. Photographs of Physical Model of FCO Spillway at Utah State University's Water Research Laboratory

9. Does the BOC have any recommendations or comments on the Oroville Dam vegetation area?

Response

1. The Design Team made a presentation regarding the history and probable causative mechanism of the Oroville Dam Embankment vegetation area. The presentation included discussions on the design and construction history of the dam with an emphasis on the internal zoning of the embankment; the core, filter, chimney and blanket drains downstream of the core; the seepage collection features; the make-up and construction of Zone 3 shell material within the downstream slope near the left dam abutment; and the final grading of the downstream slope.

   The BOC agrees with the Design Team's thorough assessment of the construction records as they relate to the observed vegetation area on the downstream slope of the embankment. The BOC notes that this condition has been observed and documented before the first filling of the reservoir, and was reported by multiple independent safety inspection boards and independent consultants with the conclusion that this is not a dam safety issue. The BOC agrees that the vegetation observed at various levels on the downstream slope near the left dam abutment (and at other locations on the downstream face) is a result of infiltration of rainfall that could be perched on lenses of fine-grained Zone 3 material and exits on the downstream face. It is the BOC's judgement that the observed vegetation areas on the downstream embankment slope are not related to seepage originating from the reservoir and are not considered a dam safety concern.

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

Response

1. The BOC recommends proceeding with development of a monitoring plan for the provisional and permanent FCO and Emergency spillways.

2. The BOC recommends that the maintenance of the gates to reduce side-seal leakage be performed now to allow close-up surveillance of the chute surface during future monitoring of the FCO spillway.

BOC RECOMMENDATIONS SUMMARY

M11-1 The BOC recommends that the drain pipes under the FCO Spillway chute slabs be cleaned and video inspected at the conclusion of construction to establish a neat baseline for future inspections.

M11-2 The BOC recommends that consideration be given to reducing the thickness of the final lift of RCC if it is determined that the 12-inch thickness becomes too difficult to compact.

M11-3 The BOC recommends that steel plates be added to the ends of the transverse anchors embedded in the vertical face of the RCC training walls of the FCO spillway, or that the ends of the anchors be bent 90 degrees to increase their pull-out resistance.

M11-4 The BOC recommends that blasting not be used to remove the provisional RCC gravity spillway training walls where the demolition is close to any permanent structural concrete slabs or walls.

M11-5 The BOC recommends that the Design Team consider reducing the diameter of the drain pipes that are proposed under the reinforced concrete chute slabs placed on RCC to allow for smaller trench cuts into the RCC.

M11-6 If the desired production rates for the construction of the secant pile cutoff wall are not achieved and the construction schedule and deadlines become a concern, the BOC recommends that the Contractor focus his resources on completing the sections of the cutoff wall at the two areas where the flow is anticipated to be concentrated and the headcutting is of greatest concern.

M11-7 The BOC endorses the Design Team's proposed revised criteria for determining the point when the secant pile drilling depth has met the requirement for 15-foot penetration into fresh or slightly weathered bedrock.

M11-8 It is the BOC's judgement that the observed vegetation areas on the downstream embankment slope are not related to seepage originating from the reservoir and are not considered a dam safety concern.

M11-9 BOC recommends proceeding with development of a monitoring plan for the provisional and permanent FCO and Emergency spillways.

M11-10 The BOC recommends that the maintenance of the gates to reduce side-seal leakage be performed now to allow close-up surveillance of the chute surface during future monitoring of the FCO spillway.

Respectfully submitted,

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

John Egbert **Paul Schweiger**