

OROVILLE EMERGENCY RECOVERY – SPILLWAYS

Board of Consultants Memorandum

DATE: September 6, 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. 20

INTRODUCTION

On Wednesday September 5, 2018, the Independent Board of Consultants (BOC) met at the Department of Water Resources (DWR) Oroville Field Division Office Main Conference Room at 7:00 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 July 16, 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 and walls in the middle section of the FCO chute (see Figure 2);
- Final surface preparation and initial placement of reinforced concrete to rehabilitate the FCO terminal structure (see Figure 3);
- Final excavation and foundation preparation for the RCC apron and buttresses for the ogee monoliths on the left side of the Emergency Spillway (see Figures 4 and 5); and
- The nearly completed RCC apron of the right side of the Emergency Spillway, Areas 1 and 2A (see Figure 6).



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



Figure 2. Construction of chute slabs and walls in the middle section of FCO chute.



Figure 3. Final surface preparation and initial placement of reinforced concrete to rehabilitate the FCO terminal structure. Photo inset shows concrete spall on the downstream face of a dentate.



Figure 4. Final excavation and foundation preparation for the RCC apron on the left side of the Emergency Spillway.



Figure 5. Final excavation and foundation preparation for the RCC apron and RCC buttress on the left side of the Emergency Spillway



Figure 6. View of Emergency Spillway completed Areas 1 and 2A. Area 2B is the foreground area.

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

- Construction progress;
- Construction schedule;
- Geology update, including status of the FCO and Emergency Spillway RCC apron foundation mapping;
- RCC apron and buttress foundation preparation;
- Emergency Spillway drain construction;
- Plans and Specifications Revision No. 10; and
- Alternative alignments being considered for the boat ramp parking access road.

On Thursday September 6, 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 July 16, 2018. Construction progress includes:

Upper FCO Chute

- Completed foundation preparation
- Placed all leveling and dental concrete
- Constructed all underdrain trenches, collectors and outfalls
- Installed 98% of the slab anchors
- Placed 47 of the 150 slabs and 2 of 50 wall sections

Middle FCO Chute

- Completed foundation preparation
- Placed all leveling and dental concrete
- Constructed all underdrains. Collectors and outfalls remain to be constructed.
- Installed all slab anchors
- Placed 171 of the 228 slabs and 54 of 76 wall sections

Terminal Structure

- Completed all demolition
- Placed 4 of the 6 concrete slabs
- Wall construction is about to begin

Emergency Spillway

- Finishing foundation excavation and preparation
- Completed installation of all monolith drilled anchors
- Completed Phase 2A RCC placement to El. 870.0 feet
- Completed 500,000 cubic yards of 700,000 cubic yards of RCC (71%)
- Completing RCC cold joint treatment this week
- Phase 2B placement which was halted August 30, 2018 for batch plant preventive maintenance is set to resume on September 10, 2018

Most construction features are ahead of schedule. For construction features that are slightly behind schedule, an effective plan has been developed and is being implemented to complete construction work on or ahead of schedule. During the last three weeks, the FCO crews averaged 40 concrete placements per week (slabs and walls). A total of 231 slabs and walls remain to be constructed. The RCC placement in the Emergency Spillway averages just under 5,000 cubic yards per day and 200,000 cubic yards of RCC remain to be placed. Realizing that production rates are likely to diminish somewhat in the final stages of both the FCO Chute and the Emergency Spillway, the BOC believes that, barring delays resulting from significant weather events, the critical elements of the project are on track to be completed by November 1, 2018.

The BOC noted a spalled area on the downstream face of one of the dentates that needs to be saw cut and chipped out before placing the new concrete overlay on the walls (see Figure 3 photo inset). It was understood by the BOC that all removal of concrete on the dentates had been finished, but no doubt, it is intended that this spalled area be prepared before the wall is repaired.

The BOC was pleased to learn that the new concrete slabs are showing significantly less shrinkage cracking than those completed in 2017 and commends the Design Team for implementing modifications to the concrete mix and placement to improve the quality of the concrete.

The BOC notes that the construction site continues to have excellent security and safety measures, is well organized, and maintained very clean.

2. Does the BOC have any recommendations or comments on the geology update?

Response

A presentation was made to the BOC regarding the ongoing geologic assessment of the spillway foundations. The presentation included geologic mapping of the uppermost FCO chute foundation, the area of the Emergency Spillway buttress and apron foundation downstream of the ogee overflow monoliths; and a discussion on drainage mitigation in this same area of the Emergency Spillway.

The BOC continues to be pleased with the thoroughness of the geologic mapping for the FCO chute and the Emergency Spillway apron, and the meticulous inspection and approval of structure foundations. The BOC recognizes that two geology-related milestones were reached since the last BOC meeting, (1) final FCO rock foundation inspection was completed on August 6, and (2) the last leveling concrete was placed on the FCO rock foundation on August 8. There is therefore now no exposed foundation rock remaining in the FCO spillway chute.

Geologic evaluation and mapping in Area 2B of the Emergency Spillway buttress and apron foundation (uppermost area downstream of the monolith section) remain to be completed. There are other geologic inspection tasks that are ongoing, such as monitoring the backfill along the outside of the FCO chute walls. The largest task that is ongoing is the transition from data collection and analysis to one of report completion and documentation while project knowledgeable staff are still onsite.

Many presentations regarding geologic conditions and evaluations have been made to the BOC during the past 20 meetings. The BOC considers these presentations to be important snap-shots that document the ongoing discovery process as construction progressed. During BOC Meeting No. 19, the BOC was informed that the final Geology Report for the Spillway Recovery Project would not be completed until the Summer of 2019. As the final BOC meeting will be completed before that time, the BOC recommends that summaries of the geologic information, even if not in final form, be presented in an abbreviated format.

3. Does the BOC have any recommendations or comments on the Emergency Spillway?

Response

- a. Confirmation of the Emergency Spillway Ogee Gravity Section Foundation.** During the field visit and in a subsequent presentation, the BOC observed excavation and cleanup of the rock foundation that is located immediately downstream of the Emergency Spillway monoliths. The geologic analysis of exposures shows the intersecting joints and fractures to be complex. However, interpretation and analysis of such features were reported to pose no adverse impacts to the stability of the monoliths. The BOC understands that the Design Team will be performing additional exploratory borings to confirm their subsurface interpretations for design issues. The BOC looks forward to reviewing the additional subsurface information.
- b. Permanent Service Road.** The BOC recommends that the current erodible service road on the RCC apron of the Emergency Spillway be removed and a permanent service road be located outside the footprint of the Emergency Spillway. The permanent access road should be configured in a manner that does not adversely impact the Emergency Spillway hydraulics.
- c. Emergency Spillway Left Abutment RCC Treatment.** The foundation conditions for the left training wall of the RCC apron in the area immediately adjacent to the non-overflow gravity monolith had been an unknown until it was decided to excavate the earth backfill to expose the bedrock along the downstream groin of the non-overflow gravity monoliths. The excavated space was backfilled with RCC and the access road that occupied this location was restored. This solution provided a good base on which to place the RCC training wall and will serve as the abutment for placement of the weir buttress. The BOC believes this was an admirable solution.

4. Does the BOC have any recommendations or comments on Revision 10 Plans & Specifications?

Response

Drains at Downstream Toe of Emergency Spillway. A presentation was made to the BOC on recent and ongoing revisions to the Emergency Spillway RCC buttress section, the drains at the toe of the Emergency Spillway Ogee Section, and

the backfill behind the FCO chute walls. The BOC concurs with the recommended changes to the design of the drain area behind the secant wall, the monolith drain extensions, and the slotted pipe drain underneath the RCC buttress. These changes are pragmatic and will take advantage of the existing excavated rock surface features while maintaining the overall function and ability to maintain the drain system.

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

Response

Topics for Discussion and Resolution for Remaining Scheduled BOC Meetings. The BOC was asked what topics of design and construction warrant inclusion in the agendas for the remaining BOC meetings. Past BOC comments and recommendations were reviewed, and the following items remain of interest:

- a. Hydraulic Evaluation of Spillway Approach Losses.** The Design Team recently completed detailed computational fluid dynamics (CFD) modelling to evaluate the discharge coefficients for the Emergency Spillway control structures (the broad-crested and ogee sections) for the full range of reservoir spill levels. The BOC believes that the approach losses to these structures also need to be evaluated, especially for the right side of the broad-crested control section when both the FCO and Emergency spillway are flowing concurrently. The BOC recommends that the Design Team perform detailed two-dimensional hydraulic modelling of the approach conditions to the FCO and Emergency Spillway assuming both spillways are conveying flows for the probable maximum flood condition. This analysis will determine the variation in the flow over the Emergency Spillway crest and the effect on the discharge capacity at various reservoir spill levels.

- b. Modelling of Emergency Spillway Buttress Section.** Technical Memorandum (SRT-EMS-HR-11), describing the detailed CFD and physical modelling of flow over sections of the buttressed Emergency Spillway Ogee structure, was provided to the BOC for review prior to BOC Meeting No. 20. In the memorandum, it was noted that the physical model studies for optimizing the buttress design for the overflow weir demonstrated that the overflow jet jumps free of the buttress steps at some stages of overflow discharge. This would likely produce a vacuum in the void since no means of access for air is

- available. This could cause alternating “make and break” collapse of the void space with undesirable noise and vibration. The addition of flow splitters to introduce air to prevent this occurrence could be considered. However, it is doubtful that this phenomenon would cause a significant performance problem for the massive buttressed overflow weir in view of the rare occasion of its use. The BOC would appreciate a presentation and discussion on this subject.
- c. Video Inspection of Spillway Drains.** The BOC recommends that the drain pipes under the FCO Spillway chute slabs and the Emergency Spillway RCC apron be cleaned, if needed, and video inspected at the end of construction to establish a baseline record for future inspections.
- d. Spillway Monitoring Plan.** The BOC believes that the 2018-2019 winter season represents what is considered a “first filling phase” for the spillways for this project and understands that the Design Team developed a detailed instrumentation and monitoring plan. An outline of this plan was presented to the BOC for review during previous meetings. The BOC recommends that all relevant instrumentation data collected during the past two years be compiled and summarized to provide a baseline for implementing the monitoring plan. “Threshold” and “action” levels for critical instrument readings should be identified based on safe performance levels assumed in the design of project components. The BOC would like to review the monitoring plan for the FCO and Emergency Spillway. The monitoring plan should include a reliable method for measuring the drain flows from the FCO spillway.
- e. Testing FCO Spillway Performance.** The BOC recommends that the FCO spillway be tested by making a controlled release during the 2018-2019 winter season provided the refilling of the reservoir accommodates such a test.
- f. Groundwater Monitoring.** The BOC recommends ongoing groundwater monitoring, especially during the wet season. The BOC believes it will be important to compare these initial “dry period” data readings with those in the future that will be recorded when the reservoir is at a higher stage or when the FCO Spillway chute experiences flows.
- g. Final Site Grading and Landscaping.** While the final site landscaping is not of particular interest to the BOC, the backfilling of the FCO training walls along the reaches where the abutments were eroded during the failure incident is of interest to the BOC and is a design feature that needs resolution.

- h. Treatment of Cracks in FCO Chute Slabs.** The BOC believes it may be of value to treat the minor surface cracks in the FCO spillway slabs that were placed in 2017 with a crystalline waterproofing product. Waterproofing treatment of concrete surfaces with these types of chemicals have effectively promoted sealing of open concrete cracks by growth of crystals.
- i. Hydrology Forecast.** Prior to BOC meeting No. 21, the BOC would appreciate receiving any weather predictions for the upcoming fall/winter season and any indications of the likelihood for early rains.

Closing Comment. An important lesson learned from past dam incidents is the need for design engineers to be involved in their projects after they go to construction to make sure that their assumptions about site conditions are correct (Post Design Construction Phase). This is especially true for fast-track dam projects in complex geologic settings like that of the spillways at Oroville Dam.

The Oroville Dam Spillway Emergency Recovery project has truly been precedent setting. All construction has occurred during two limited construction seasons (approximately late May to November 1 of 2017 and 2018). During this time, the reservoir and required water deliveries were kept in operation. Geologic exploration, engineering design, and construction planning were performed as ongoing parallel processes with constant feedback necessitating changes in each of these three activities as new data was obtained.

The BOC is impressed with the level of communication between the geologists, design engineers, contractor, and regulators from the beginning of construction to the present. In almost every BOC meeting, the geologists have provided meaningful briefings on foundation conditions for critical structures as the subsurface exploration and excavation for these structures progressed. In response to this information the designers have thoughtfully and deliberately modified and adapted their designs to accommodate site conditions. The contractor has repeatedly shown flexibility and innovation in implementing design changes and constructing these project features. The regulatory agencies have actively participated in the process by sharing their expertise and providing an independent and thorough review of all designs and construction work. Examples of this occurring during this meeting include:

1. Modifying the Emergency Spillway control structure drainage system to accommodate the exposed foundation;
2. Modifying the drainage system under the RCC apron at the downstream secant pile wall;
3. The design of the left Emergency Spillway RCC abutment;
4. Adjusting the outside footing of the FCO spillway training walls (along toe of rock slope) in the upper section of the spillway to accommodate the existing excavated rock features;
5. Adjusting the RCC mix design and rate of placement in response to a temporary shortage of fly ash to minimize impacts to the schedule and maximize the quality of the placed RCC by keeping a fresh RCC working surface and avoiding cold joints.

The BOC believes the Oroville Dam Emergency Spillway Recovery Project is an outstanding example of how complex dam construction projects should be completed.

BOC RECOMMENDATIONS SUMMARY

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| M20-1 | The BOC recommends that summaries of the geologic information, even if not in final form, be presented in an abbreviated format. |
| M20-2 | The BOC recommends the current erodible service road on the RCC apron of the Emergency Spillway be removed and a permanent service road be located outside the footprint of the Emergency Spillway. |
| M20-3 | The BOC recommends that the Design Team perform detailed two-dimensional hydraulic modelling of the approach conditions to the FCO and Emergency Spillway assuming both spillways are conveying flows for the probable maximum flood condition. |
| M20-4 | The BOC recommends that the drain pipes under the FCO Spillway chute slabs and the Emergency Spillway RCC apron be cleaned, if needed, and video inspected at the end of construction to establish a baseline record for future inspections. |

- M20-5 The BOC recommends that all instrumentation data collected during the past two years be compiled and summarized to provide a baseline for implementing the monitoring plan.
- M20-6 The BOC recommends that the FCO spillway be tested by making a controlled release during the 2018-2019 winter season provided the refilling of the reservoir accommodates such a test.
- M20-7 The BOC recommends ongoing groundwater monitoring, especially during the wet season.
- M20-8 Prior to BOC meeting No. 21, the BOC would appreciate receiving any weather predictions for the upcoming fall/winter season and any indications of the likelihood for early rains.

Respectfully submitted,



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