

OROVILLE EMERGENCY RECOVERY – SPILLWAYS

Board of Consultants Memorandum

DATE: May 20, 2019

TO: Mr. Mike Inamine, Program Manager
Oroville Emergency Recovery – Spillways
California Department of Water Resources

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

SUBJECT: Memorandum No. 23

INTRODUCTION

On Monday May 20, 2019, the Independent Board of Consultants (BOC) met 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 at the Department of Water Resources (DWR) Oroville Field Division Office Main Conference Room at 8:00 am to listen to reports on the first activation of the replaced Oroville FCO (Flood Control Outlet) spillway that occurred in April, 2019.

Presentations were made to the BOC on the following:

- FCO surveillance during the first spill; and
- Post first-spill inspection of the FCO

The BOC then departed around 9:30 am to the dam site to inspect the FCO and emergency spillway. Confined space training was provided at the site before performing the inspection. The reservoir was at elevation 891 feet at the time of the inspection (about 77 feet above the FCO fixed spillway crest invert elevation). The entire FCO chute from the spillway gates to the dentates was inspected by the BOC, except for areas that were wet from flowing water where safety and slippery conditions were a concern.

At 1:00 pm, the BOC returned to the Oroville Field Division Office Main Conference Room to deliberate and prepare their report. A reading of the BOC's draft report was made at 4:30 pm 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. Based on meeting presentations and Mr. Kollgaard's observations of the first spill, does the BOC find the FCO Spillway performance meets the intent of the design?***

Response

A presentation was made by the DWR Division of Operations and Maintenance summarizing the preplanned monitoring program that was executed for the first release of significant flow through the FCO since the FCO chute was replaced following the February 2017 incident. The primary monitoring of the April 2019 spillway release was performed by a team of approximately 16 persons divided into two 12-hour shifts (8 persons per shift) who observed and monitored the performance of the spillway continuously. In addition to observing the spillway flows, the team monitored readings from the 36 piezometers measuring water pressure under the spillway, underseepage from 40 FCO drains, and movement at 71 surface monuments mounted on top of the spillway walls. Drones were also employed to obtain observations within the spillway at multiple vantage points.

In addition to the DWR performance monitoring team, on Wednesday April 3, 2019 (on the second day of the spillway release), Board of Consultants member Eric Kollgaard traveled to Oroville to observe the flow in the reconstructed FCO spillway chute. Mr. Kollgaard observed the energy dissipation of the dentate structure and reported that it appeared to be working as designed, effectively dissipating the energy of the flow prior to entering the Feather River. The surface of the flow in the steep section of the spillway chute was well aerated and roughened by waves. The travelling wave pattern moving down the chute observed in the live camera feed during the first day of operation on April 2, was less pronounced on April 3, due to the greater depth of the increased discharge. The flow in the spillway chute appeared to be well-aerated with the initial air induced by the FCO gate structure piers making white water the entire length of the upper section of the chute to the vertical bend. Observed from the FCO control structure, the only drain outlets which appeared to be wet from drain flow were those located near the point where the slope of the spillway chute transitions to a 4H:1V slope.

It was noted that a small fine fin of spray was directed into the flow at each vertical joint in the chute walls. The spray was produced by the configuration of the joint with beveled edges of the wall concrete at the vertical joint. This behavior does not affect the flow pattern and is of no consequence.

Mr. Kollgaard attended the 2:00 pm daily briefing meeting held by the operations and monitoring staff and was advised on the operational activity plus current monitoring and surveillance procedures. Of particular interest was the monitoring of the spillway underdrains. The largest drain outflow reported, at that time, was a half-inch depth measured at the outlet of one of the drain pipes. The drain flow was characterized as minimal.

Mr. Kollgaard reports that, from viewing the live camera feed during the day of increased flow at about 26,000 cfs on April 7, the appearance of the deeper flow was similarly well-behaved. It was noted that the tendency of the traveling waves observed during the earlier lower flow was subdued.

The presentation by DWR summarizing the performance of the FCO spillway chute during the entire April 2019 event indicated that the chute floor piezometers showed only a muted response to the elevated reservoir level, the releases in the spillway, and the concurrent rainfall. The piezometers showed that no water pressure affected the spillway slabs. The underdrains showed minimal seepage under the slabs. The survey monuments showed no movement of the spillway structure. The observed drain flows were so small that the monitoring team was unable to quantify them accurately with the current measuring system. The maximum drain flow observed was estimated as 5 gallons per minute. This is considered to be an insignificant amount of seepage that is well within the design expectation for the spillway. While not directly comparable because the former drain system also collected the wall backfill infiltration, it is estimated that many of the underdrains before the FCO chute was replaced were flowing at more than 1,200 gallons per minute.

Based on the meeting presentations and Mr. Kollgaard's observations of the first FCO spill, the BOC finds that the FCO Spillway performance fully meets the intent of the design. The BOC was pleased with the thoroughness of the monitoring program carried out during initial operation and believes the Oroville FCO Spillway may have the distinction of being the most extensively and intensely monitored spillway in the United States. The BOC believes that this intense level of monitoring may not be sustainable and can be adjusted as the successful performance of the spillway continues to be confirmed for more and higher flow events.

2. Does the BOC find the spillway safe for continued use?

Response

1. In its report at the conclusion of the previous BOC Meeting No. 22, the BOC stated that it had provided engineering review and advice throughout the period of the design and construction of the Oroville Spillways Recovery project. The BOC's involvement has spanned the concurrent design and the construction phases of the project. As stated in the response to Question 1 above, after the first release through the FCO chute, the BOC was presented with the results of visual observations, instrumentation monitoring, and detailed inspections of the conditions of the various spillway elements that were performed following the spillway release. The BOC also performed its own independent visual observation and inspection.

The BOC inspected the full length of the FCO Spillway on May 20, 2019 from inside the spillway. Select photographs taken by BOC members are presented on Figures 1 through 5. Collectively, the BOC noted only minor cosmetic differences from when the FCO spillway was inspected prior to passing flow. The differences included a handful of transverse joints missing several inches of flexible sealant, a spalled shallow small concrete repair, and a roughened surface of a slab finish (see photographs in Figures 4 and 5).

On the basis of its close involvement in the review of design documents, its knowledge of the foundation conditions and materials used in construction, its observation during the various phases of construction, and the satisfactory performance of the spillway during the first operational release, the BOC affirms that the reconstructed Oroville Spillway has been completed in accordance with the design documents, and is judged to be safe for continued use.



Figure 1. Photographs Taken During BOC Inspection of FCO

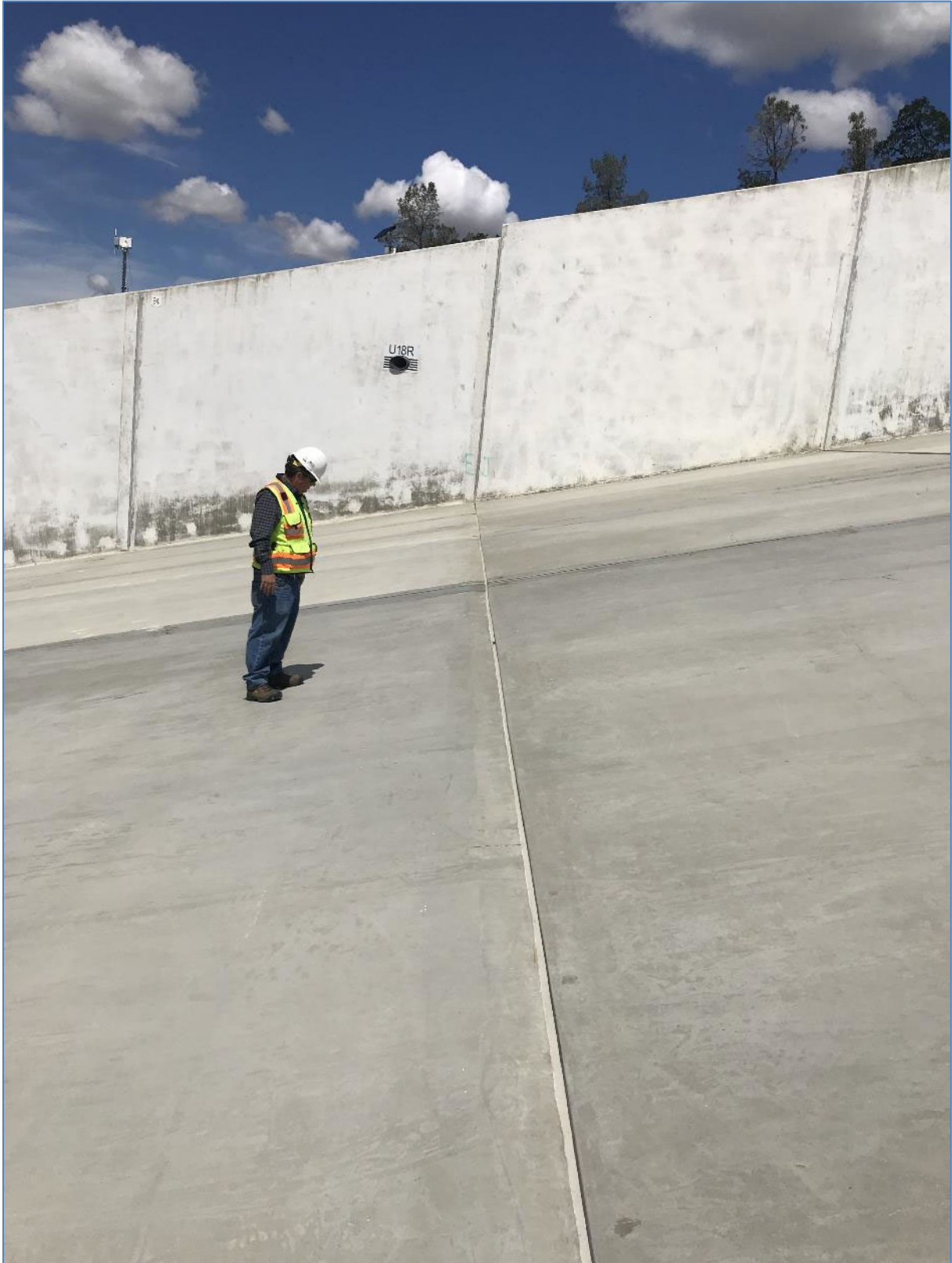


Figure 2. Photographs Taken During BOC Inspection of FCO



Figure 3. Photographs Taken During BOC Inspection of FCO



Figure 4. Photographs Taken During BOC Inspection of FCO



Figure 5. Photographs Taken During BOC Inspection of FCO

3. Does the BOC have any comments or recommendations from their FCO inspection?

Response

1. The BOC noted during the chute inspection that, as anticipated, many of the hairline cracks originally observed on the surface of the chute slabs were healed by the natural action of the cement in the concrete. This behavior is expected to continue with time. Never-the-less, the BOC reiterates its recommendation to apply a crystalline-type waterproofing system to the surface of the spillway slabs according to the manufacturer's directions provided it can be applied without adversely impacting the existing smooth surface finish of the slabs.
2. The BOC observed all the threaded bolts protruding from the spillway walls that were used to mount the staff gages on the inside face of the walls (see Figure 6). Although not intentional, these bolts provided an opportunity to monitor for cavitation damage since such a protrusion into the flow should initiate cavitation. All of the bolts at each staff gage mounting location that were below the flow line of the recent FCO spillway release showed no evidence of cavitation damage. The BOC recommends that the bolts used to fasten the staff gages to the inside face of the spillway walls be removed flush with the face of the wall, and that the staff gages be replaced with the staff gage information painted on the walls.
3. The BOC received a detailed briefing from the DWR during this BOC Meeting regarding the field observations and significant events which took place during the first spill. This briefing included a summary of their findings. The BOC also walked and observed the entire length and width of the FCO chute in order to confirm the physical condition of the slabs, walls, joints and drainage systems. The BOC believes the spill event confirms their previous observations that the quality of the constructed spillway is superior. The slabs and walls are very smooth and the construction joints are intact. The BOC looks forward to future uneventful flow events in the FCO Chute.



Figure 6. Photographs of staff gage anchoring bolts protruding from the spillway wall.

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

Response

The BOC views the method of estimating flow by photography of flow depth comparison with the optical markings taken from across the spillway chute, or photographed by use of drones, is not a practical long-term monitoring procedure given the minimal amount of seepage emanating from the spillway chute drains. Flow volumes estimated on the basis of this method cannot be determined with sufficient accuracy to identify trends or changes in the monitored data with time and different magnitudes of flow releases. The BOC recommends that a method be devised to more accurately determine the flow rate from the FCO chute underdrains using a timed volumetric approach. The flow from the wall drains that collect rainfall infiltration in the wall backfill is not, in the opinion of the BOC, a long-term monitoring requirement.

Concluding Comments:

The recent FCO spillway flow which occurred as planned, showed that the efforts of the past two years have been successful. The design process was transparent, with input provided by all stakeholders (owner, designers, regulators and the construction contractor). The BOC believes this is a world-class project that will give the State of California many years of uneventful service.

As noted in the *Independent Forensic Team Report for the Oroville Dam Spillway Incident*, there are many lessons to be learned from this project that are of value to the dam safety community at large. During the subsequent design, construction, and monitoring phases of this project, many innovative data collection, analyses, improved defensive measure design details, construction techniques, and surveillance and monitoring procedures were developed for the spillways. The BOC encourages DWR and its consultants to share this information with the dam safety community by publishing technical papers and making presentations at national dam safety conferences and other venues.

BOC RECOMMENDATIONS SUMMARY

M23-1 The BOC reiterates its recommendation to apply a crystalline-type waterproofing system to the surface of the spillway slabs according to the manufacturer's directions provided it can be applied without adversely impacting the existing smooth surface finish of the slabs.

M23-2 The BOC recommends that the bolts used to fasten the staff gages to the inside face of the spillway walls be removed flush with the face of the walls and that the staff gages be replaced with the staff gage information painted on the walls.

M23-3 The BOC recommends that a method be devised to determine the flow rate from the FCO chute underdrains using a timed volumetric approach.

Respectfully submitted,



Eric B. Kollgaard



Faiz Makdisi



Kerry Cato



John Egbert



Paul Schweiger



STATE OF CALIFORNIA
 DEPARTMENT OF WATER RESOURCES
 OROVILLE EMERGENCY RECOVERY – SPILLWAYS

Meeting Title: Board of Consultants

Date: May 20, 2019, Oroville Field Division Main Conference Room, CA

Call in: 866.434.5269 – participant code: 553.1154 (host code: 182.6529)

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Barry, Rob	DWR	
Blackett, Frank	FERC	Frank Blackett
Boyer, Doug	FERC	
Brown, Dale	DWR	Dale
Burke, Joe	DWR	
Cato, Kerry	IC	Kerry Cato
Craddock, Ted	DWR	Craddock (1st name)
Dossey, Kevin	DWR	Kevin Dossey
Egbert, John	IC	John Egbert
Escobar, Sergio	DWR	Sergio Escobar
Ford, David	DFCE	David Ford
Fortner, Mark	GEI	
Hall, Craig	GEI	Craig Hall
Harder, Les	HDR	Les Harder
Inamine, Mike	DWR	Mike Inamine
Kollgaard, Eric	IC	Eric B. Kollgaard
Kuttel, Jeanne	DWR	
Lewis, Liz	GEI	Liz Lewis
Lopes, Jim	DWR	Jim Lopes
Makdisi, Faiz	IC	Faiz Makdisi
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Nichols, Holly	DWR	Holly Nichols
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Sarkisian, David	DWR	David Sarkisian
Schweiger, Paul	IC	Paul Schweiger
Torres, Ralph	DWR	
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