

OROVILLE COMPREHENSIVE NEEDS ASSESSMENT

Independent Review Board Memorandum

DATE: October 18, 2019

TO: Mr. Sergio Escobar, Project Manager
Oroville Comprehensive Needs Assessment
California Department of Water Resources

FROM: Independent Review Board for
Oroville Comprehensive Needs Assessment

SUBJECT: Report No. 6

On Thursday October 17, 2019, the Independent Review Board (IRB) met at the Department of Water Resources (DWR) Oroville Field Division Office Main Conference Room at 9:00 am for briefings regarding progress on the Comprehensive Needs Assessment (CNA). The IRB met with representatives from the DWR Division of Engineering (DOE), DWR Division of Operations and Maintenance (DOM), the Federal Energy Regulatory Commission (FERC), and industry consultants working on the CNA for status updates on:

- The overall project and project schedule,
- Writing of task reports,
- Emergency Spillway erosion potential,
- IRB Comments Log,
- Progress of Tasks 1, 3, 4 and 5, and
- Open discussion of the CNA study.

During the morning of Friday October 18, 2019, the IRB deliberated and prepared a draft of this report. Comments made on the individual presentations and the IRB's responses to DWR questions for the IRB are included in this report. A reading of the IRB's draft report was made to representatives from DWR, DOE, DOM, FERC, and industry consultants working on the project at 12:00 pm. The meeting was adjourned following the reading of the report.

All IRB members were present on both days including (Elizabeth) Betty Andrews, Lelio Mejia, Bruce Muller, Dan Wade and Paul Schweiger. A list of meeting participants for both days is attached.

QUESTIONS FOR THE IRB

1. Does the IRB have any recommendations or comments on the project status update?

Response:

The IRB was informed that the CNA is on schedule with each Task Team having completed their existing condition assessments and risk reduction measure development. Review of this work by senior members of the Integration Team is ongoing. A workshop to formulate alternative plans is scheduled to begin next week.

The Task Teams completed their existing condition assessments with input from the recent 2019 FERC Part 12 PFMA/L2RA workshops that were conducted independently of the CNA. The final total number of potential failure modes (PFMs) considered is 372, of which 235 were screened out and 137 were developed. Of the 137 PFMs that were developed, 12 were evaluated but not carried forward. 125 PFMs were fully developed into 411 scenarios with 2,055 risk scores assigned based on their probability of occurrence and consequences (public safety, regulatory compliance, flexibility and reliability for water delivery, flexibility and reliability for other SWP purposes, and financial consequences). For the PFMs that were screened out or set aside, the reason for doing so was explained and documented, and reviewed for concurrence by senior members of the Integration Team.

The probability of occurrence and life safety consequence estimates for the PFMs developed from the recent 2019 FERC Part 12 process were also compared with those independently developed by the CNA effort. While the scope and processes for each study was not identical, the majority of PFM cases compared show general agreement. In cases where there are appreciable differences, the CNA Task teams reviewed, or are reviewing the basis for their estimates and plan to meet with L2RA leadership to deliberate on the differences.

Using the risk scores, each PFM scenario was plotted on a risk matrix and assigned a color (red, grey, amber, or green) to visually differentiate the severity of the risk. PFMs assigned the color red have the greatest risk, whereas PFMs

assigned the color green have the least risk. PFMs assigned the color green were further subdivided into two zones of greater and lesser risk (“upper green” and “lower green”, respectively). PFMs in the grey zone have extremely remote probabilities but potentially high consequences. The outcome of the PFM binning process is summarized in Table 1 below.

Table 1
Summary of PFM Binning by Task

Task	Red	Gray	Amber	Upper Green	Lower Green	Total
Task 1	1	0	0	1	0	2
Task 3	2	3	11	13	10	39
Task 4	0	0	0	9	24	33
Task 5	1	15	10	20	5	51
Total	4	18	21	43	39	125

In general, the current risk for the Oroville Dam complex was determined to be relatively low, with only four PFMs binned within the red cells of the matrix that are plotted along the lower risk zone at the border of the red and the grey/amber cells. As previously presented, the CNA is using an expanded version of the Asset Management Risk Matrix to allow for consideration of the potential high risk associated with public safety and financial consequences of some of the PFMs evaluated as part of the CNA effort. As a result, these two consequence categories drive the most significant areas of risk for the PFMs considered by the CNA. The CNA therefore used the results in these two consequence categories to focus their development of potential risk reduction measures.

To account for uncertainty in the CNA’s assessment of probability of failure and/or consequences, each Task Team considered potential risk reduction measures for those PFMs that had at least one loading-consequence pair with a risk value on either the risk matrix for public safety or the risk matrix for financial consequences, that were not in the lower green region of the matrix. The only exceptions were PFMs in the grey region that were determined to have a total probability of failure that was exceedingly remote, for which development of potential risk reduction

measures was optional, and left to the judgment of the Task Team. Thus, PFMs were identified as “important” if they had at least one loading-consequence pair with a risk value in any of the areas on the risk matrix for public safety or the risk matrix for financial impact not designated as lower green.

Based on the results of the CNA existing condition assessments presented, in general, the primary risk drivers for Oroville Dam are related to: (1) potential seismic damage to the gated reinforced concrete FCO structure, (2) erosion downstream of the emergency spillway roller-compacted concrete (RCC) apron and secant pile wall during flood flows, and (3) overtopping of embankment dams (Oroville Dam, Bidwell Bar Camp Saddle Dam, and the Parish Camp Saddle Dam) during extreme floods.

Each Task Team also completed measure development for each “important PFM”. This involved first identifying initial conceptual measures, screening these measures for fatal flaws to obtain candidate measures, consolidating the candidate measures by qualitatively selecting the measures that provide the greatest potential risk reduction and best fit CNA design considerations, and finally identifying feasible measures with the greatest practicality and risk reduction as evaluated by semi-quantitative risk assessment.

The IRB concurs with the CNA Team’s approach to completing the condition assessments, screening and categorizing the PFMs, and selecting feasible measures to reduce risk for important PFMs. The IRB reiterates that it believes that this effort ranks among the most significant and in-depth assessments of PFMs ever considered and developed for a dam project and continues to be pleased with the progress made by the CNA Team. The IRB offers specific comments and recommendations related to each Task in their response to Question 4 below.

2. Does the IRB have any recommendations or comments on the task reports status update?

Response:

The IRB was provided a preliminary draft report for Task 3 for review and was informed that the reports for the other tasks were in a similar state of development. The IRB continues to appreciate the CNA Team’s commitment to developing and updating the reports as work is completed, and providing the IRB with periodic

reviews of task reports under development. Below are some general comments and suggestions, recognizing that the reports are a work in progress:

1. The IRB suggests that the report titles include the full task name identifier. By clearly identifying the focus of the task on the cover, the reader will be apprised of the content, even if not personally familiar with the CNA's task structure.
2. The task reports are designed as stand-alone documents, each providing consistent information about the context, purpose, and process of the CNA effort. The IRB supports this approach, as the readers of these documents may only be interested in a single topical area and therefore read only one report. At the same time, this approach does mean that each report contains a tremendous volume of information. The IRB therefore endorses the use of a consistent template, to the extent practical, for each report, which facilitates the rapid identification of relevant sections to users of multiple task reports. Additionally, the IRB was pleased to see the inclusion of a consistently-structured Executive Summary in each task report that provides key elements and findings of the subject Task, even to readers with only an opportunity for cursory review.
3. Because of the volume of information in each task report, the IRB suggests that the task reports make extensive use of graphics and callout boxes to make the content more readily approachable and digestible.
4. The IRB appreciates the use of color coding to help visually convey risk levels. It is effective and should be used in tables and graphics throughout the reports. The IRB suggests that consideration be given to providing additional color gradations to separate each of the green and red zones of the risk matrix into two bands, one indicative of a greater level of risk, and one indicative of a lesser level of risk (e.g., light green and light red).
5. Given the great utility of color in conveying information, the IRB also suggests that the graphics editor of the task reports consider the use of modified color schemes for the risk matrix that are accessible to color blind readers.
6. The IRB appreciates the inclusion of an extensive glossary in each task report, which provides definitions for key terms, including resilience, robustness, reliability, and redundancy.

7. The IRB recommends that the reference to the “four Rs of a resilient system,” be reviewed in context of IRB Recommendation 1-6 (see IRB Report No. 1). In addition to the quantitative and qualitative risk-informed decision-making approaches outlined for evaluating problems and alternatives, the IRB recommended that the CNA Project Team also evaluate and document existing components and alternatives with respect to their robustness, redundancy, reliability, and resiliency, as is the current practice of the US Army Corps of Engineers (USACE) for evaluating, planning, and designing dam modifications. Definitions for these terms are available in *USACE ER 1110-2-1156, Safety of Dams – Policy and Procedure*.
8. The CNA organizational chart includes a body identified as the Technical Steering Committee. The IRB suggests that the role of that body with respect to the CNA be described in the document, such as in the table identifying CNA roles and responsibilities.
9. The IRB suggests that effort be made to develop a graphical approach to displaying the contributions to risk made by all PFMs carried forward under each task in a single display. Such a graphic would be valuable to include in each task report and in the Executive Summary. This would provide a means of quickly understanding the relative contributions to risk of each of the most significant PFMs.
10. The IRB suggests that each task report discuss why risk reduction measures were not considered for some PFMs that plotted in the grey cells of the risk matrix.
11. The IRB suggests that tables presenting risk levels associated with different PFMs and different consequence categories limit their risk display to the identification of the color zone they fall in, rather than including numeric risk levels. Numeric risk levels indicate the product of the frequency rating and the consequence severity. As such, these risk scores are not directly indicative of comparative risk level across PFMs and consequence categories, which is instead best addressed by color zonation. The IRB appreciates that numeric risk levels are useful for indicating the risk reduction provided by measures, but suggests that their use be limited to that purpose.
12. The IRB recommends that each appendix providing the detailed justification for the screening of measures be reviewed and edited to ensure that

justifications are clear, well-documented, and use of terminology is consistent among Task Teams.

3. Does the IRB have any recommendations or comments on the Emergency Spillway erosion potential?

Response:

An erosion analysis of the Emergency Spillway downstream of the secant pile cutoff wall was performed for increments of flow from 6,000 cfs up to 421,000 cfs. The recent analysis performed to better understand the erosion potential within the Emergency Spillway utilizes best available methodology as proposed by Annandale (1995). The IRB appreciates the clear graphical presentation of results which are very helpful to understand the spatial distribution and volume of erosion that may take place over a range of flows considered up to the PMF event. The new findings show less erosion potential than early estimates; nevertheless, the recent analysis indicates that the volume of material that could be eroded downstream of the new RCC apron and secant pile wall is still significant. It also shows that the majority of the erosion occurs for emergency spillway flows significantly less than the PMF event.

The modelling approach appears to make reasonable assumptions for purposes of the current planning study based on interpolation of the available data. The IRB was pleased that the model validation check that was performed generated results that compare reasonably well with the actual erosion observed in the 2017 spillway incident. Nevertheless, it should be acknowledged that uncertainty associated with the erosion potential estimates for the range of flows considered could be large.

4. Does the IRB have any recommendations or comments on the updates for Tasks 1, 3, 4 or 5?

Response:

General Comments: The documentation of each PFM is very detailed and clearly indicates the loading condition, the full description of the potential failure mode from initiation to failure, supporting information with sketches, performance monitoring information, listing of factors that make the PFM more likely and less likely, discussion of failure likelihood and confidence of likelihood estimate(s),

areas of uncertainty, consequences, and interim risk reduction measures. This documentation will become an important reference for Oroville Dam.

The IRB notes that when describing the PFMs from initiation to failure, the potential for emergency intervention was not always considered. For some PFMs, the probability of unsuccessful intervention was estimated and included in the determination of the likelihood of failure. For other PFMs, intervention does not appear to have been considered. Not considering intervention in the PFMs for the assessment of existing conditions is conservative and would tend to overestimate the likelihood of failure. The IRB understands that for some PFMs, such as erosion of the Emergency Spillway during extreme floods, intervention is not possible. However, for some PFMs, like many of those associated with [REDACTED], intervention should be considered, especially when evaluating feasible risk reduction measures. For example, the PFMs with the apparent greatest risk are related to [REDACTED]

The IRB recommends that the potential for emergency intervention be considered and included in the evaluation of risk reduction measures, and discussed in the reports for each task.

Task 1 – Emergency Spillway:

The presentation for Task 1 summarized the process used to develop and screen PFMs and potential mitigation measures. Of the 11 PFMs considered, 8 were developed and 2 were carried forward for consideration of mitigation measures for risk reduction. The IRB believes that the range of PFMs considered is appropriate, and that the two PFMs that were carried forward appropriately highlight the primary vulnerabilities of the Emergency Spillway, namely: (1) erosion of hillside materials into the diversion pool leading to tailwater impacts to the Hyatt Powerplant; and (2) scour downstream of the secant pile wall leading to instability of the wall and progressive undercutting of the RCC apron and damage or failure of the Emergency Spillway concrete monolith weir. The consequences for both of these PFMs were ultimately determined to be controlled by financial impacts. With the recent modifications to the Emergency Spillway, failure and breaching of the Emergency Spillway concrete monolith weir was determined to be so remote a

possibility as to be non-credible or not reasonable to postulate. Nine feasible measures were developed to address these PFMs.

Of the 50 conceptual measures considered, 11 consolidated candidate measures were screened to 9 feasible measures that were carried forward to be considered for risk reduction of the PFMs. Although most of the feasible measures considered would achieve significant risk reduction, the analysis confirms that the greatest risk reduction can be achieved by lining the channel either with RCC or structural concrete.

In addition to the Emergency Spillway erosion potential analysis (see response to Question 3), other supporting analyses include scour potential immediately downstream of the existing secant pile wall, structural analysis of the existing RCC apron, and structural analysis of a potential future structural concrete spillway. The analyses appear to make use of reasonable assumptions for a planning level study and are pending peer review.

Task 3 – FCO Headworks and Main Spillway:

Similar to the other task presentations, the volume and quality of work presented by the Task 3 Team was extensive and impressive. The IRB noted that the [REDACTED] [REDACTED] is a leading concern, but that there are not specific measures identified to address this concern. This is not unexpected, given that concerns about [REDACTED] are an industry-wide challenge. These [REDACTED] and even more difficult to access to implement repairs if they become necessary. The ensuing conversation revealed that DWR is actively engaged in researching methods to monitor the health [REDACTED], and partnering with other organizations that face similar challenges. With no recognized industry method for addressing this issue, many organizations are tempted to dismiss the issue as an intractable problem that cannot be solved. The IRB encourages DWR to use the CNA report to document a proactive approach to researching and addressing this issue. Such an approach could include:

- Organizational understanding of the issue
- Commitment to researching methods to monitor and assess the condition of [REDACTED]
- Implementation of the best available monitoring methods to assure that changes in performance can be identified prior a potential failure

- Commitment of resources to researching or seeking research proposals for [REDACTED]

Task 4 – Low Level Outlet:

Of the 34 PFMs considered under Task 4 – Low Level Outlet, 33 were carried forward highlighting the primary high-risk vulnerabilities, including [REDACTED]

[REDACTED]
[REDACTED]
[REDACTED] In addition,

[REDACTED] to the overall Oroville Dam complex.

Several helpful studies have been completed to support the development of potential mitigation measures, including a “seismic walkdown” of Hyatt Powerplant facilities, evaluation of outlet capacity to meet DSOD drawdown guidelines, consideration of historic operating levels, and evaluation of potential new low-level outlet options and alignments.

Of the 57 potential mitigation measures considered, 13 consolidated candidate measures were carried forward of which 5 were considered feasible. The feasible measures were generally shown to reduce probability of failure by an order of magnitude, thereby reducing overall risk without reduction in the consequence of failure.

The IRB commends the Task 4 Team for appropriately investing significant time and effort into evaluation of additional low-level outlet capacity to enhance overall reliability of the Oroville Dam complex. The IRB considers this work to be well-conceived for the purposes of the CNA planning study, and agrees that consideration of low-level outlet(s) would significantly reduce risk for numerous PFMs identified in various CNA tasks. The feasible alternative concepts that were presented included: (1) an “upper” outlet in the right abutment to provide full FCO redundancy to meet DSOD reservoir drawdown guidelines; and (2) a “lower” outlet in either the right or left abutment to provide full Hyatt Powerplant outlet redundancy. The IRB recommends that consideration be given to a measure for a single low-level outlet that would provide both FCO drawdown redundancy and Hyatt Powerplant outlet redundancy, rather than two separate outlets. Such an

outlet could be designed to allow higher than desirable flow velocities for short durations for emergency situations.

Task 5 – Embankments: The IRB appreciates the effort made by the CNA Team in Task 5 to assess the existing conditions and to develop measures to improve the safety and reliability of the dam embankments. The IRB concurs with the overall process followed by the CNA Team for the screening and evaluation of PFMs, the assessment of risk scores, and the development of feasible measures to address the identified vulnerabilities. The selected feasible measures also seem appropriate and provide a solid basis to formulate alternative plans to reduce risk and improve the safety and reliability of the dams. Although the IRB agrees with the highest vulnerabilities identified, the IRB suggests that the process for identification of the highest vulnerabilities on the basis of the assessed PFM risks, needs to be clarified. It is not clear, for example, how PFM [REDACTED], which received a public safety consequence risk score of 21 and was assigned risk matrix color amber, was ultimately identified as a high-risk vulnerability, while PFM [REDACTED] which received the same public safety consequence risk score and risk matrix color, was not.

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

Response:

- 1. Peer Review Supporting Analyses.** Several of the task briefings identified supporting analyses that will become part of the CNA Task Team reports as appendices or memoranda. The IRB recommends that DWR ensure that each supporting analysis be peer reviewed prior to considering it complete. As noted in IRB Report No. 5 (IRB Recommendation No. 5-1), the IRB encourages the Project Integration Team to maintain records of their reviews for future reference and that these records be expanded beyond reviewing the screened PFMs.
- 2. Wildfire Threats.** The IRB suggests DWR assess the threat of wildfire as a possible initiator of failure modes. The propensity for wildfires in the vicinity of Oroville Dam warrant discussion of this threat as a potential threat to the safety of the dam and/or appurtenant structures.

- 3. Low Level Outlet PFMs.** The IRB recognizes that the CNA Team seems to be challenged to connect the notion of a low-level outlet to a specific failure mode. DWR must keep in mind that potential failure mode analysis and risk analysis are simply tools to ensure a broad perspective of issues that affect dam safety. The team may find it more appropriate to consider the evacuation capability of the appurtenant structures of the dam in a broader context. The ability to lower the reservoir level is a primary means of responding to a developing dam safety emergency (emergency intervention) by reducing the water loads on the dam and structures. A dam's low level outlet must have two key features: (1) the ability to lower the reservoir to a level that substantially reduces risk to the public, and (2) reliability to perform its function when needed. For Oroville Dam, both of these characteristics can be substantially improved with a new high capacity low level outlet. The Hyatt Power Plant and RVOS only marginally meet these needs. A new low level outlet would provide redundancy, improve reliability, and substantially improve DWR's ability to lower the risk associated with multiple potential failure modes by increasing their ability to successfully intervene if a failure mode began to develop.
- 4. Communicating Study Outcomes.** The assessment of vulnerabilities and development of measures has been appropriately framed around risk reduction. Generally, most of the identified risks are associated with small probabilities of occurrence and, even though some of them involve potentially large consequences, they are considered tolerable and are not indicative of safety deficiencies. Nonetheless, measures that reduce risk and improve the reliability of the facilities are essential to the management of project safety. Thus, the IRB suggests that in communicating the outcomes of the study, including proposed measures and recommended plans, the CNA Team consider framing the study outcomes around the reliability and safety improvement aspects of the study, as well as risk reduction.
- 5. Binning PFMs.** The IRB concurs with the CNA Team's approach to addressing uncertainty by differentiating between the "upper green" and "lower green" cells in the risk matrix. As noted in our response to Question 2, the IRB recommends that a similar distinction be made with the red cells, especially since all four of the PFMs that are within the red matrix fall along the peripheral of the amber cells, and are marginally in the red. This would provide a meaningful refinement to the visual understanding of risk for the project.

The IRB looks forward to hearing about the following topics at the next IRB meeting:

- Task Reports
- Alternative Plans
- CNA Report
- Public CNA Report

Concluding Remark:

The IRB appreciates the continued enthusiasm demonstrated by the CNA Team and the progress that has been made. The IRB looks forward to seeing the results of the formulation of alternative plans and their refinement.

IRB RECOMMENDATIONS SUMMARY

- M06-1 The IRB recommends that the reference to the “four Rs of a resilient system,” be reviewed in context of IRB Recommendation 1-6 (see IRB Report No. 1).
- M06-2 The IRB recommends that each appendix providing the detailed justification for the screening of measures be reviewed and edited to ensure that justifications are clear, well-documented, and use of terminology is consistent among Task Teams.
- M06-3 The IRB recommends that the potential for emergency intervention be considered and included in the evaluation of risk reduction measures, and discussed in the reports for each task.
- M06-4 The IRB recommends that consideration be given to a measure for a single low-level outlet that would provide both FCO drawdown redundancy and Hyatt Powerplant outlet redundancy, rather than two separate outlets.
- M06-5 The IRB recommends that DWR ensure that each supporting analysis be peer reviewed prior to considering it complete.
- M06-6 As in distinguishing “upper green” from “lower green,” the IRB recommends that a similar distinction be made with the red cells,

especially since all four of the PFMs that are within the red matrix fall along the peripheral of the amber cells, and are marginally in the red.

Respectfully submitted,


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