DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
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CECW-LRD

FEB 2 3 2015

MEMORANDUM FOR THE ASSISTANT SECRETARY OF THE ARMY (CIVIL WORKS)

SUBJECT: Center Hill Dam, Caney Fork River, DeKalb County, TN, Supplemental Major Rehabilitation Evaluation Report and Environmental Assessment -- Final USACE Response to Independent External Peer Review

1. Independent, objective peer review is regarded as a critical element in ensuring the reliability of scientific and engineering analyses. USACE conducted the Independent External Peer Review (IEPR) for the subject project in accordance with Section 2034 of the Water Resources Development Act of 2007, USACE Engineer Circular (EC) 1165-2-214, and the Office of Management and Budget's Final Information Quality Bulletin for Peer Review (2004).

2. A U.S. Treasury Code 501(c)(3) non-profit science and technology organization, independent and free of conflicts of interest, established and administered the peer review Panel. The IEPR Panel consisted of five members with expertise in geotechnical engineering, engineering geology, hydraulic and hydrologic engineering, economics/planning, and environmental planning/National Environmental Policy Act impact assessment.

3. The final written agency responses to the IEPR are hereby approved. The enclosed document contains the final written responses of the Chief of Engineers to the issues raised and the recommendations contained in the IEPR report. The IEPR report and the USACE responses have been coordinated with the vertical team and will be posted on the Internet, as required in EC 1165-2-214.

4. If you have any questions on this matter, please contact me or Ms. Yvonne Prettyman-Beck, at 202-761-4670.

Encl

STEVEN L. STOCKTON, P.E.
Director of Civil Works

Center Hill Dam Safety
Supplemental Major Rehabilitation Evaluation Report and Environmental Assessment
Caney Fork River, DeKalb County, Tennessee

US Army Corps of Engineers Response to Independent External Review
February 2015

Center Hill Dam is currently classified Dam Safety Action Classification (DSAC) 1, the highest risk classification assigned to dams requiring urgent and compelling action. Dam safety classification is based on an assessment of probability of failure and incremental risk. Center Hill Dam was authorized for modification in 2006 based on an approved Major Rehabilitation Evaluation Report (MRER). The guidelines for conducting the 2006 MRER predate the current risk management process. A Supplement to the MRER was prepared to document the 2012-2014 risk assessment and to describe the risk-based rationale for scope changes to the 2006 MRER recommendations. The Supplemental Major Rehabilitation Evaluation Report (SMRER) risk assessment concluded that the barrier wall and grout curtain in the main dam embankment, as constructed or being constructed, reduces risk to within tolerable limits. The risk-based assessment also concludes that seepage in the right abutment and right rim results in no credible failure modes, therefore the SMRER recommends that elements of the original remediation plan that would address this issue, be eliminated. The risk-based findings of the SMRER also show that the saddle dam embankment in the current condition (no action) or the saddle dam with a barrier wall (2006 recommendation) both have risk above the tolerable limit threshold because the risk assessment identified overtopping of the saddle dam as an additional credible failure mode. A roller compacted concrete (RCC) reinforcing berm downstream of the saddle dam provides risk reduction to a tolerable limit, is less costly than a barrier wall, and is recommended in lieu of the barrier wall at the saddle dam.

USACE conducted a Type I Independent External Peer Review (IEPR) for the Center Hill Dam Safety Supplemental Major Rehabilitation Evaluation Report (SMRER) and Environmental Assessment (EA) in accordance with Section 2034 of the Water Resources Development Act of 2007, EC 1165-2-214, and the Office of Management and Budget's *Final Information Quality Bulletin for Peer Review* (2004).

The goal of the US Army Corps of Engineers (USACE) Civil Works program is to always provide scientifically sound, sustainable water resources solutions for the nation. The USACE review processes are essential to ensuring project safety and quality of the products USACE provides to the American people. USACE engaged Battelle Memorial Institute (Battelle), a non-profit science and technology organization, experienced in establishing and administering peer review Panels, to conduct the IEPR of the Center

Hill Dam SMRER and EA, Caney Fork River, DeKalb County, Tennessee. Battelle issued the final IEPR Report on 6 November, 2013.

Based on the technical content of the Center Hill Dam review documents and the overall scope of the project, Battelle selected candidates for the IEPR review Panel in the fields of geotechnical engineering, engineering geology, hydraulics and hydrology, economics and plan formulation, and environmental planning and National Environmental Policy Act (NEPA) impact assessment. Overall, the review Panel identified and documented twelve comments. Two comments were identified as having high significance, six were identified as having medium significance, and four were identified as having low significance. The following discussions present the USACE Final Response to the twelve comments. Further details on each comment, such as the Basis for Comment, Significance, and Recommendations for Resolution can be found in the IEPR Final Report referenced above.

1. Comment – *High Significance*: Uncertainty exists regarding whether the Center Hill Dam's erodible fuse plug will fail within 30 minutes, as designed.

The erodible fuse plug is a soil and rock structure built in the early 1990's on the Center Hill auxiliary dam embankment. The purpose of the fuse plug is to add spillway capacity to the project. The fuse plug was designed to act as a normal dam until overtopped by an extreme flood. At that time it is intended to quickly erode and the space created will help pass the design storm flood flow and prevent the main dam from overtopping.

This comment included four recommendations for resolution, three of which have been adopted and one which has not been adopted as discussed below.

USACE Response: Adopted.

Action Taken: The IEPR Panel recommended (1) the fuse plug failure process be better described. USACE added a summary of the existing fuse plug failure data, including the original physical model testing of the fuse plug in Section 4.3 of the Roller Compacted Concrete (RCC) Berm Design Documentation Report (DDR). The Panel also recommended (2) the SMRER include discussions regarding the sensitivity analyses conducted on the timing of fuse plug erosion and the elevation at which erosion begins. USACE has added information on the sensitivity analyses in Section 6.5.2 of Chapter 6 of the report and Section 4.3 of the DDR. The analyses indicate that even if the fuse plug takes two hours to erode (four times longer than the 30 minutes designed), the peak pool elevation of the lake would only encroach on the main dam's freeboard and not overtop the main dam. IEPR Panel recommendation (4) was to consider the need for additional freeboard for the main dam embankment. This recommendation was adopted for consideration as part of the Center Hill project's Probable Maximum Flood (PMF) design storm update. Results indicate no change in peak pool elevation and therefore no encroachment into the main dam freeboard. Once current remedial measures are completed with construction of the RCC reinforcing

berm, a Post Implementation Evaluation (PIE) will be conducted for the Center Hill project. Further risk-based evaluation of the potential for overtopping and/or wave overwash will be accomplished at that time.

USACE Response: Not Adopted.

USACE did not adopt recommendation (3) to develop an additional risk assessment to further evaluate the potential of the fuse plug not operating as designed during design of the RCC berm. Detailed study and consideration of the fuse plug design, model testing, construction and operation were integral to this failure mode during the formal baseline risk assessment as documented in the SMRER. The risk of the fuse plug failure to operate is deemed to be extremely low. Furthermore, sensitivity analysis conducted on the timing of the fuse plug provides confidence the consequences of longer erosion time is minimal.

2. Comment – *High Significance*: The assumption that the alkali-aggregate reaction (AAR) increases normal stress on monolith contacts or other surfaces within the monoliths (and therefore adds to surface frictional resistance) is not supported by quantitative data.

This comment included four recommendations for resolution, all of which have been adopted as discussed below.

USACE Response: Adopted.

Action Taken: The IEPR Panel recommended that (1) USACE further clarify the assumptions regarding AAR and its applicability to Potential Failure Mode (PFM) 19A, deterioration of the leaking construction concrete lift joint on Monolith 11 causing sliding failure, and PFM 18B, spillway gate binding due to AAR. The Panel also recommended that USACE (2) review the rationale for eliminating both PFMs. USACE adopted these recommendations. The risk assessment's assumptions and conclusions for determining PFM 19A and PFM 18B are not significant failure modes was described in Section 5.3 of the SMRER. The conclusions were based on findings in a 2002 Finite Element Analysis which used core samples taken throughout the concrete dam. The analysis was reviewed and added to Appendix H - Structural Documentation as Item 7. The Panel also recommended that USACE (3) determine the seismic loading on PFM 19A, and (4) examine the downstream impacts if the PFMs are validated. USACE adopted these recommendations also. In order to verify the risk assessment conclusions, a finite element model evaluating stresses on Monolith 11 is underway and will be completed by May 2015. The model analysis will specifically consider the stability of Monolith 11 and the seismic loading on PFM 19A. If either PFM is determined credible, the downstream impacts will be evaluated.

3. Comment – *Medium Significance*: Several potential failure modes (PFMs) may have been dismissed prematurely, thereby potentially affecting project benefits.

This comment included four recommendations for resolution, none of which have been adopted as discussed below.

USACE Response: Not adopted.

Several saddle failure modes were considered with a barrier wall in place, which was the initial risk assessment baseline condition. These failure modes were discussed in the SMRER and were dismissed as not credible with the current recommended RCC berm in place. The IEPR Panel recommended (1) reconsideration of these saddle dam failure modes without the barrier wall in place. The three Potential Failure Modes are– PFM 6 (seepage and piping through the alluvium-bedrock contact of the saddle dam), PFM 8 (seepage between the original saddle dam and the bottom concrete of the fuse plug), and PFM 10 (solution features forming in the saddle dam that deform the concrete slab on which the fuse plug was constructed). USACE did not adopt this recommendation because the berm will be founded on competent rock, thereby eliminating seepage paths (PFM 6). Furthermore, filling the space between the RCC berm and the downstream saddle dam slope with compacted material will reduce seepage gradients and reduce the probability of piping materials (PFM 8). Compacted fill material also reduces the probability of PFM 10 because an unfiltered seepage exit point no longer exists since the space is now filled with compacted material. The probability of progression of piping erosion through the fill is less due to reduced velocity and a resultant reduction in shear forces acting as the erosive mechanism to scour material. Therefore, USACE concluded a reconsideration of all these failure modes would not impact project benefits or plan selection. The IEPR team recommended USACE (2) recalculate failure probability, (3) review the selected alternative, and if necessary, (4) revise environmental documentation, all of which were not adopted. USACE provided the Panel the additional information (as generally discussed above) to support the conclusion that the probability of PFMs 6, 8, and 10 occurrences remains very low without a barrier wall at the saddle dam. The report text was revised to clarify the failure mode conditions without a barrier wall in Section 5.3 of the SMRER.

4. Comment – *Medium Significance*: The system response probabilities for Potential Failure Modes (PFMs) 7A, 7B, 7C, and 7D and their relationship to PFM 7 are not clearly presented in the documentation, and the choice of PFM 7C over PFM 7D is not fully supported.

This comment included four recommendations for resolution, all of which have been adopted as discussed below.

USACE Response: Adopted.

Action Taken: USACE agreed that event trees and added documentation and discussion of the various additional RCC berm alternatives developed for the saddle dam would strengthen the SMRER. These alternatives are PFMs 7A, 7B, 7C, and 7D (7A - saddle dam current condition without barrier wall constructed, do nothing alternative; 7B- saddle dam without barrier wall constructed, with RCC berm; 7C- saddle dam without barrier wall constructed, with RCC berm and area between berm and saddle dam filled with material; and 7D - saddle dam without barrier wall, no fill, with RCC berm and fuse gates added). USACE subsequently adopted the recommendation to (1) review and added each PFM event tree to the SMRER. The event trees and discussions were added as Sections 5.8.2.1 through 5.8.2.4. The Panel recommended (2) USACE recalculate as necessary the event tree node probabilities and (3) overall probability of failure, annual costs, and annual benefits of PFMs 7B, 7C and 7D. The event trees were thoroughly reviewed and no node probability revisions were deemed necessary; however, benefits and costs of each of the alternatives were updated. Recommendation (4) was to reflect the results of recommendations 1 through 3 and revise the SMRER as necessary. USACE adopted this recommendation and additional discussion of these saddle dam alternatives, the evaluation process and conclusions were added to Chapter 10 of the SMRER, Conclusions and Recommendations.

5. Comment – *Medium Significance*: Apparent discrepancies in different sets of the dam breach modeling information and inconsistencies in the level of detail between different analyses made it difficult to assess the dam breach model.

This comment included five recommendations for resolution, all of which have been adopted.

USACE Response: Adopted.

Action Taken: USACE adopted Panel recommendations to (1) review and add documentation of the dam breach modeling information to strengthen the SMRER. Section 6.4 has been revised for completeness and the information has been verified against the actual data used in the model. USACE has also adopted Panel recommendations to (2) expand dam breach Table 6-10 to include bottom breach elevations and side slopes and (3) add Table 6-12 to include saddle dam breach with the RCC berm in place. Additional Panel recommendations were adopted to (4) add discussion of the sensitivity analyses represented by fuse plug failure scenarios, added as Section 6.4.8 and to (5) review the upper confidence curve versus the 2013 pool curve shown in Figure 6-19 (now Figure 6-7). USACE reviewed these curves and concluded the upper confidence limit of the Annual Exceedence Probability (AEP) curve is in compliance with the latest risk assessment process for establishing a range of variability of values for the AEP of the Probable Maximum Flood.

6. Comment – *Medium Significance*: The project documentation does not account for the possibility that additional seeps could develop in the groin area and impact the main dam embankment.

This comment included four recommendations for resolution; one of the recommendations was adopted and three were not adopted as discussed below.

USACE Response: Adopted.

Action Taken: USACE adopted Panel recommendation (4) to install additional piezometers and continue seepage monitoring during and after the current construction.

USACE Response: Not Adopted.

The Panel recommended: (1) develop an event tree for seepage around the left side of the barrier wall and, if justified, (2) evaluate additional grout curtain, and (3) further barrier wall extension. Recommendations (1) through (3) were not adopted for the reasons described next. During the final stage of the 2008-2010 main dam and left rim grouting contract, detailed geologic information was obtained at the left end of the main dam embankment. The presence of karst features in this area necessitated lengthening the barrier wall by 155 feet into the left rim to drive the potential seepage path gradient further away from the embankment. Based on joint orientation, this extension of the main dam barrier wall into the left abutment should significantly extend seepage paths away from the left abutment portion of the embankment. The possibility of an end run around the extended barrier wall was considered as low probability and is discussed in the SMRER Section 10.6.1.2. An existing minor seep near the toe of the groin runs clear rather than muddy and there are no signs indicative of stress. In addition, instrumentation reactions were monitored during the main dam grouting program and during the groin grouting and did not produce responses that might indicate a potential risk. The extension of the barrier wall and continued monitoring of instrumentation will significantly reduce the risk of additional seeps impacting the embankment.

7. Comment – *Medium Significance*: The effects of climate change on the Probable Maximum Flood (PMF) and the magnitude of the reservoir elevation have not been evaluated.

This comment included four recommendations for resolution; two of which were adopted and two were not adopted.

USACE Response: Adopted.

Action Taken: The Panel recommended USACE (2) add discussion of how potential effects of climate change were considered during plan development. The discussion was added to Section 6.2.1 of the SMRER. In general, climate variation was analyzed by showing the uncertainties in the hydrologic modeling. This probabilistic change is

shown best in the development of the pool frequency curve (frequency of various lake levels) and most notably the procedure for estimating the probability of occurrence of the Inflow Design Flood. Guidance provided by the Risk Management Center (RMC) was utilized to develop a wide range of probability estimates and a representative curve was constructed based on the estimates. The climate variance can be estimated by utilizing the confidence extents of the adopted curve. The Panel further recommended (3) climate change considerations be added to the Environmental Assessment (EA). This discussion was added in EA Section 3.4.

USACE Response: Not Adopted.

The Panel recommended USACE (1) describe the effects of climate change on the tentatively selected plan, including an evaluation of the PMF and the magnitude of the reservoir elevation that would result. This recommendation was not adopted. Discussion on the magnitude of the reservoir elevation resulting from climate change is already an inherent part of the modeling and uncertainty parameters as discussed in above and in Section 6 of the SMRER. Also, current FEMA guidance states there is no generally accepted procedure for estimating climate change effects on precipitation depths and recommends that until such methods are identified, extreme precipitation should be evaluated in a conservative yet realistic manner. The Center Hill Probable Maximum Precipitation (PMP) was recently updated in this manner and the Probable Maximum Flood (PMF) was determined not to increase. The Panel recommendation (4) to revise the PFM probabilities of failure based on climate change was also not adopted, again, because this essentially was already accomplished with the risk methodologies in the risk assessment and also because the recent PMF update did not result in an increase in the PMF reservoir elevation.

8. Comment – *Medium Significance*: The assumption that upper and lower leaks in the right rim are primarily due to solution channels along the bedding planes is not valid.

This comment included three recommendations for resolution, two of which have been adopted and one of which was not adopted, as discussed below.

USACE Response: Adopted.

Action Taken: The Panel recommended USACE (1) revise text in the SMRER and Appendix G to clarify the nature of the right rim flow. USACE revised SMRER Section 3.2.5 and Section 1.1.3 of Appendix G for clarity. USACE also adopted Panel recommendation (2) and the right rim seeps will continue to be monitored through the life of the Center Hill project.

USACE Response: Not Adopted.

USACE did not adopt Panel recommendation (3) to evaluate the role of vertical joints contributing to the right abutment leaks. This effort was fully accomplished for the risk estimate as described in SMRER Appendix G, Section 1.1.3 and further analysis will not alter the project recommendations.

9. Comment – *Low Significance*: Several topics customarily addressed to comply with the National Environmental Policy Act (NEPA) either are not discussed in the project documentation or received minimal discussion, and some sections of the environmental assessment (EA) refer to measures that are no longer part of the tentatively selected plan.

This comment included five recommendations for resolution, four of which have been adopted and one of which was not adopted as discussed below.

USACE Response: Adopted.

Action Taken: The Panel recommended (2) the Environmental Assessment (EA) Supplement 3 be revised to add unaddressed measures that are still part of the tentatively selected plan. USACE adopted this recommendation and the EA Supplement 3 was extensively revised to fully address the tentatively selected plan, including items addressed in previous EAs that remain part of the SMRER tentatively selected plan. These were summarized in SMRER Section 3.2.7. Panel recommendation (3) was adopted and a discussion was added to summarize project public outreach activities in Section 7 of the EA. Recommendation (4) was also adopted and discussions of short-term, temporary impacts of construction activities on noise, air quality, water quality, migratory birds, fisheries, and traffic were added to Section 3 of the EA. A discussion on karst species (cave dwelling) considerations was Panel recommendation (5) and was also adopted. This discussion was added to EA Section 3.

USACE Response: Not Adopted.

The Panel recommended (1) removing from the SMRER and EA all discussion of previously recommended actions no longer part of the tentatively selected plan. USACE did not adopt this recommendation. These items recommended in the 2006 MRER and subsequently removed from the project scope were primarily grouting and cave filling. These items were removed from the project scope based on the 2011-2014 risk analysis which determined these features provide no actionable (catastrophic) failure modes related to life safety. The EA Supplement 3 addresses all project decisions, both saddle dam-related and other, including initially planned work now removed from the scope.

10. Comment – *Low Significance*: It is unclear whether the economic analysis has taken into consideration the annualized benefits of power and water supply

from the Center Hill Dam in relation to the annualized cost of the most likely alternative.

This comment included two recommendations for resolution, neither of which have been adopted as discussed below.

USACE Response: Not Adopted.

The Panel recommended USACE (1) provide a basis for using payment agreements to calculate lost benefits instead of using costs incurred by the consumer for alternative water and power supply. The recommendation was not adopted as a full explanation of the direct losses of service, the value of benefits provided by the dam, is provided in Appendix E of the SMRER. The power and water supply benefits of the project are the payments that would be lost in the event of a saddle dam failure. For water supply, the quantity of water supplied was used as defined in the IWR 2011-R-06 report, Appendix C. The reallocation contract costs were updated to current dollars. For hydropower, the annual kilowatts of electricity produced between 2005 and 2009 were averaged and then multiplied by 8.22 cents per kilowatt-hour (the 2010 average of all use sectors for the region) to obtain the average annual value of production. Repair of the saddle was estimated to take 3 years after failure. The sum of each year's loss was discounted to present worth. Recommendation (2) was a continuance of (1) requesting a revision of the benefit analysis if change in cost to the user is the proper metric for calculating benefits. Recommendation (2) was not adopted because it is not applicable since the standard dam failure lost benefit economics are to use lost payments rather than increase in alternative costs.

11. Comment – *Low Significance*: It is not clear what approach will be used to cap or restore an area of hazardous materials that leached from treated timber formerly stored on the site.

This comment included two recommendations for resolution of contaminated soil on adjacent land owned by the State of TN and needed for temporary work area for construction of the RCC berm. Both recommendations have been adopted as discussed below.

USACE Response: Adopted.

Action Taken: The Panel recommendations include: (1) develop a set of remedial options and (2) describe options in the EA. The approximate six cubic yards of contaminated soil was on State of Tennessee property slated to be used as temporary work area for the future Corps contractor in the upcoming saddle dam RCC berm construction contract. USACE adopted recommendation (1) and options for avoidance and removal of the contaminated area were formulated and considered in conjunction with State personnel. In April of 2014, the State acted on the plan to remove the

contaminated soil from the site and provided USACE a Letter of No Further Action in June 2014. As recommended in (2) the discussion was added to EA Section 3.17.

12. Comment – *Low Significance*: A detailed correlation between discontinuity orientations and known seepage pathways (karst features) has not been established.

This comment included three recommendations for resolution, none of which were adopted as discussed below.

USACE Response: Not Adopted.

The Panel recommendations were (1) plot all available 200 to 500 discontinuity orientation data on a stereonet and determine the most prominent orientations, (2) plot all known orientations of karst features (seepage paths, caves, cavities) on a stereonet and determine orientations of these features and (3) compare the principal orientations from recommendations (1) and (2) to identify the orientations that preferentially favor karst development. USACE did not adopt these recommendations because a detailed correlation between the discontinuity orientations and known seepage pathways is sufficiently summarized in Section 1.1.3 of Appendix G – Karst Development and Structural Geology in the Vicinity of Center Hill Dam. The summary of the geologic data is adequate to provide the risk assessment team an understanding of the geologic complexities of the site. It is not the intent of the SMRER process to include detailed mapping program and rock orientation data collected for Center Hill Dam. Previous mapping efforts were summarized, and stereonets of these fracture sets across the site are presented in as Figure 1-10 in Appendix G of the SMRER. Bedding planes at the site are near horizontal and the cave orientations are known and mapped. Text within the comprehensive Appendix G was examined for clarity and revised as needed. Further, geological details will continue to be gathered and continually assessed as the barrier wall project construction continues to ensure that present and future engineers and geologists have the best possible data available to understand both the issues presented by the foundation and the measures taken to address potential risk.