April 15, 2015

MEMORANDUM TO: Joel Munday, Director
Division of Reactor Projects
Region II

FROM: Mirela Gavrilas, Deputy Director ***/RA/***
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

SUBJECT: FINAL RESPONSE TO TASK INTERFACE AGREEMENT 2014-06, REGARDING THE ADEQUACY OF THE BROWNS FERRY NUCLEAR STATION FLOODING ANALYSIS

By memorandum dated August 18, 2014 (Agencywide Documents Access and Management System Accession No. ML14227A671), the U.S. Nuclear Regulatory Commission (NRC) Region II Office requested technical assistance from the Office of Nuclear Reactor Regulation (NRR) to conduct a technical assessment on the "pre-HESCO flood level," and to answer the following questions regarding "pre-HESCO flood level" at Brown Ferry Nuclear Station (BFN).

1. Is the licensee's use of the Hydrologic Engineering Center's River Analysis System (HEC-RAS) modeling software as a substitution for the Simulated Open Channel Hydraulic (SOCH) model software in their probable maximum flood (PMF) determinations an acceptable substitution for determination of past operability?

2. Is the analysis provided by Tennessee Valley Authority to determine the pre-HESCO flood levels adequately performed?

3. Is the licensee's determination that the unanalyzed condition associated with flooding did not result in BFN being in a condition that significantly degraded plant safety with respect to the PMF elevation prior to the HESCO modular flood barriers being installed supported by the licensee's analysis?

The NRR staff position can be found in Section 3.0 of the enclosure.

Enclosure:
Task Interface Agreement

CONTACT: Holly D. Cruz, NRR/DPR
(301) 415-1053

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TASK INTERFACE AGREEMENT 2014-06

BROWNS FERRY NUCLEAR STATION

DESIGN BASIS FLOOD FOR FINAL SAFETY ANALYSIS REPORT

SECTION 2.4 HYDROLOGICAL ENGINEERING

1.0 INTRODUCTION

On December 30, 2009, Tennessee Valley Authority (TVA) completed the installation of HESCO flood barriers on the embankments of four dams as an interim and immediate correction to prevent overtopping flows if the probable maximum flood (PMF) occurs. The HESCO is a commercial brand of sand baskets used as flood barriers against flood overtopping at a dam. Hereafter, the "pre-HESCO flood level" is defined as a result from the conditions of upstream overtopping flow and dam failures during PMF event, but not including HESCO flood barriers installed in 2009 and dam modifications performed between 1982 and 1997.

The U.S. Nuclear Regulatory Commission (NRC) Region II Office questioned the validity of the re-calculated PMF elevation using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) model, as the aforementioned "pre-HESCO flood level." As indicated in the Licensee Event Report (LER) 50-259/2013-001-01, the pre-HESCO flood level at Browns Ferry Nuclear Station (BFN) is 571.5 feet.

By memorandum dated August 18, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14227A671), the NRC Region II Office requested technical assistance from the Office of Nuclear Reactor Regulation (NRR) to conduct a technical assessment on the "pre-HESCO flood level," and to answer the following questions regarding "pre-HESCO flood level" at BFN.

1. Is the licensee's use of the HEC-RAS modeling software as a substitution for the Simulated Open Channel Hydraulic (SOCH) model software in their PMF determinations an acceptable substitution for determination of past operability?

2. Is the analysis provided by TVA to determine the pre-HESCO flood levels adequately performed?

3. Is the licensee's determination that the unanalyzed condition associated with flooding did not result in BFN being in a condition that significantly degraded plant safety with respect to the PMF elevation prior to the HESCO modular flood barriers being installed supported by the licensee's analysis?

ENCLOSURE

2.0 BACKGROUND

In 2009, TVA identified four dams that would fail from potential overtopping flow during a PMF event according to updated computations by the SOCH model. All of the hypothetical dam failures, including the Cherokee, Fort Loudoun, Tellico, and Watts Bar dams, are located upstream from Watts Bar (WBN), Sequoyah (SQN), and BFN power plants. The failures of the dams would have potential adverse impact on all downstream WBN, SQN, and BFN nuclear power plants. BFN is located downstream from WBN and SQN approximately 235 miles. The issue of potential dam failures was identified during hydrology reviews for the Bellefonte Plant.

When TVA identified those hypothetical dam failures in 2009, the updated flood computational results with dam failures only provided the flood elevations for WBN and SQN, but did not provide the flood elevation at BFN. As the results of the updated flood computation, TVA submitted license amendment requests (LARs) to the NRC for approval to change the design basis flood elevations for both WBN and SQN. Currently, the LAR of WBN has been approved, but the LAR of SQN is under NRC staff review. As of May 30, 2013, TVA completed the updated flood computations for BFN, based on the 7,980 square mile storm centered at Bulls Gap similar to WBN and SQN. To compute the flood elevation for BFN, TVA used HEC-RAS model instead of SOCH model, which was used to compute the flood elevations for WBN and SQN in 2009. HEC-RAS model was subsequently used to calculate the flood elevation for WBN in a September 30, 2014, submittal to the NRC.

Licensee's Position:

According to the computational result of HEC-RAS model in 2013, TVA presented the updated flood elevation 571.5 feet for BFN, which is below the licensing basis flood elevation 572.5 feet. The licensing basis flood elevation 572.5 feet was computed by SOCH model at the time of the Operating License issuance.

As TVA stated in Item IV, Analysis of Event, of Licensee Event Report (LER) 50-259/2013-001-01, a new HEC-RAS modeling completed on May 30, 2013, regarding PMF elevation 571.5 feet at BFN did not result in significantly degraded plant safety.

The HEC-RAS modeling included 7,980 square mile storm centered at Bulls Gap as a control storm to produce the worst overtopping and breaching flood to BFN. HEC-RAS model was used to simulate flood elevations without HESCO flood barriers and without the dam modifications from 1982 to 1997.

TVA replaced SOCH model with HEC-RAS model in order to acquire the computational results in an expedient way. The HEC-RAS model was compared to SOCH model. TVA conducted model comparisons and concluded that both computational results were similar.

As a summary, Table 1 shows insignificant difference among the PMF elevations computed by SOCH and HEC-RAS as noted the storms and hydrologic assumptions are different.

Table 1: Record of Computed PMF Elevations

Document	Model	PMP Storm	PMF elevation (feet)
Final Safety Analysis Report (FSAR)	SOCH	7,980 sq. miles	572.5
Updated Final Safety Analysis Report (UFSAR) Amendment 25	SOCH	21,400 sq. miles	571.7
LER 50-259/2013-001-01	HEC-RAS	7,980 sq. miles	571.5

3.0 EVALUATION

The NRR staff provides the assessment results after reviewing TVA's HEC-RAS model, as well as its supporting data and documents. Not only did the NRR staff focus on the questions asked by Region II office to perform the technical evaluation, but also reviewed and examined the HEC-RAS model setup, boundary and initial conditions, dam failure rules, flow rating curves to assure the adequacy of PMF modeling.

The NRR staff found that the HEC-RAS model calibration for BFN was not completed and the model is lacking simulations for a few dam failures and tributary flows in some upstream extensions. The complete calibration of the HEC-RAS model for BFN will be reviewed in another work scope after TVA corrects for the inadequate setup of the HEC-RAS model for BFN. The inadequacy and incompleteness of TVA's HEC-RAS model are addressed in Questions 2 and 3 of this TIA.

Question 1:

Is the licensee's use of the HEC-RAS modeling software as a substitution for the SOCH model software in their PMF determinations an acceptable substitution for determination of past operability?

Response: Yes.
TVA developed the SOCH model for computing flood elevations along the Tennessee River and selected tributaries. The HEC-RAS model, References 1 and 2, was developed by the U.S. Army Corps of Engineers for computing flood elevations, which is not only a standard model for hydraulic engineering practice, but also a present-day model. Both SOCH and HEC-RAS models are based on the same hydraulic engineering theory, although their equations are in different forms.

In the FSAR of BFN, TVA indicated that the unsteady flow routings were simulated with the method published in the Journal of Hydraulics Division, Volume 95, No. HY5, American Society of Civil Engineers (ASCE), September 1969 (Reference 3). Although in the FSAR, TVA did not clearly specify "SOCH model" as their method to simulate unsteady flow routing, the NRR staff verified that the method published by ASCE (Reference 3) was identical to the SOCH model. Therefore, the NRR staff considers that the SOCH was originally applied for computing PMF elevation at BFN as a design basis flood elevation.

In 2013, TVA used the HEC-RAS model, instead of the SOCH model, to compute the PMF elevation at the BFN associated with upstream dam failures. The NRR staff could not verify the HEC-RAS model calibration was completed. In 2014, TVA calibrated the HEC-RAS model for tributaries of Tennessee River in WBN LAR submittal. This model calibration in 2014 is not consistent with the HEC-RAS model performed in 2013. The NRR staff would expect to see the model calibrated for portions of the river closer to the BFN site, using the two worst case recorded storms. The HEC-RAS model is one of the preferable methods as stated in NUREG/CR 7046 for an example to simulate dam breach outflow. The NRR staff considers the HEC-RAS model as being acceptable according to NUREG/CR 7046 (Reference 4, ADAMS Accession No. ML11321A195).

Further, the NRR staff found that TVA had tested both HEC-RAS and SOCH models for computing flood elevations. TVA concluded the numerical solutions were practically identical or had minimal differences (Reference 5, ADAMS Accession No. ML100550757) when the input data to both models was the same. In TVA's supporting document, the NRR staff found that TVA followed Quality Assurance Criteria of Appendix B to Title 10 of the *Code for Federal Regulations* (10 CFR) Part 50 to document the details of HEC-RAS computations.

In fact, TVA had applied HEC-RAS model in WBN LAR for computing PMF elevation associated with hydrologic failures of upstream dams in the Tennessee River Watershed. In the WBN LAR, the HEC-RAS model was accepted by the NRC staff to update the calculated PMF elevation at WBN (Reference 6, ADAMS Accession No. ML15005A314).

The NRR staff evaluated HEC-RAS model and considered the model to be a methodology that meets NUREG/CR 7046, which has guided NRC staff as the acceptable standards of systematic approach for dam breach simulation. Also, Federal Emergency Management Agency (FEMA) has accepted HEC-RAS model as one of standard hydraulic engineering practices for computing flood elevations. Furthermore, TVA followed RG 1.59 Revision 2, ANS 2.8, NUREG/CR 7046, the Appendix B quality assurance criteria of 10 CFR Part 50, and 10 CFR 50.59 to re-calculate the PMF elevation. Therefore, the HEC-RAS computational model is acceptable for computing PMF elevation at the BFN under the specific conditions of 7,980 square mile storm centered at Bulls Gap as well as a few designated dam failures. Based on the aforementioned NRC regulations and guidelines, the NRR staff considers the HEC-RAS model acceptable to evaluate the PMF scenario at BFN.

Question 2:

Is the analysis provided by TVA to determine the pre-HESCO flood levels adequately performed?

Response: No.
NRR staff reviewed TVA's supporting documents (EDMS Verification Package for LER 50-259/2013-001-01, Reference 7), as well as TVA's electronic files from the Certrec IMS website. The supporting documents and electronic files included HEC-RAS input data files, Microsoft spreadsheets, and their related text files which illustrated the input data and assumptions for the HEC-RAS model.

TVA set up the dam failure cases in the HEC-RAS model for the condition prior to physically modifying dams and installing HESCO flood barriers on upstream dam embankments. Under a 7,980 square mile storm centered at Bulls Gap, the model simulated Tellico, Fort Loudoun, Watts Bar, Chickamauga, Nickajack, and Guntersville dams for overtopping and failure.

The NRR staff found that the failure of Cherokee Dam was not included in the HEC-RAS model. TVA excluding Cherokee Dam failure in the HEC-RAS model is not adequate because in the LER 50-259 (Reference 8, ADAMS Accession No. ML13169A246) TVA identified Cherokee Dam would be overtopping and would be a failure under a PMF condition. In Reference 7, as shown in Item 2 on page 226 of 266, TVA assumed that during the 7,980 square mile storm all overtopped earth structures would fail. The other dams in overtopping conditions were indicated on pages 229 and 230 of 266 in Reference 7. Thus, those identified dams should fail based on the TVA's assumption.

Also, Melton Hill dam was set by TVA as a non-failure dam in the HEC-RAS model. The NRR staff found that the non-failure Melton Hill dam contradicts the dam safety evaluation described in the LAR for WBN, which is located approximately 235 miles upstream from BFN. In the LAR for WBN, the Melton Hill dam was evaluated to be a failure dam during the 7,980 square mile storm centered at Bulls Gap in the upstream watershed. Thus, the non-failure of Melton Hill dam was not adequately set up in the HEC-RAS model for the PMF computation for BFN.

In addition to Melton Hill dam, other designated dam failure simulations, as shown on page 229 of 266 of Reference 6, were not included in the HEC-RAS model. They were Boone, Cherokee, and Douglas dams.

Although the correction of the failures of Melton Hill, Boone, Cherokee, and Douglas dams in the HEC-RAS model may not be critical to the computed PMF elevation at Browns Ferry, the NRR staff considers the modeling to be inadequate and in need of revision.

The design basis of the PMF elevation at 572.5 feet was originally determined by SOCH model, which is not determined by the HEC-RAS model. Although both SOCH and HEC-RAS models are based on same hydraulic engineering theory, the computational procedure and model setup are different. Thus, HEC-RAS may not generate the same results as the SOCH model. But, both computational results should be comparable.

Given the inadequacy of modeling dam failures, some tributary streams not included in the model, and the apparent lack of calibration, the NRR staff would need to see revisions to the HEC-RAS model before the computational results could be used to assess any safety implications at the BFN site.

Question 3:

Is the licensee's determination that the unanalyzed condition associated with flooding did not result in Browns Ferry Nuclear (BFN) being in a condition that significantly degraded plant safety with respect to the probable maximum flood (PMF) elevation prior to the HESCO modular flood barriers being installed supported by the licensee's analysis?

Response: The NRR staff cannot determine if BFN plant safety was significantly degraded based on the existing modeling assumptions made by TVA. These assumptions will need to be modified by the licensee and the model re-run to look at the results.

The NRR staff found that a few upstream tributaries and some dams designated to fail were not included in the HEC-RAS model. The NRR staff concludes that 571.5 feet of the computed flood elevation by HEC-RAS model cannot be assured due to inadequate setup for the dam failures in the HEC-RAS model. Therefore, either the degraded or non-degraded safety at BFN cannot be validated according to the 571.5 feet of HEC-RAS modeling result.

4.0 REGULATORY REQUIREMENTS

The regulation at 10 CFR Part 50, Appendix A, General Design Criteria (GDC)-2, Design bases for protection against natural phenomena, for operating license, as it relates to (1) appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena.

As retained for historical record, Appendix A of the BFN FSAR Amendment 25 states that the design bases of Units 1, 2, and 3 were reevaluated at the time of initial FSAR preparation against the criteria of the Atomic Energy Commission (AEC) proposed GDC for Nuclear Power Plants, July 1967. In the GDC-2, Performance Standards (Category A), it relates to the design bases so established that shall reflect: (a) appropriate consideration of the most severe of these natural phenomena that have been recorded for the site and the surrounding area and (b) an appropriate margin for withstanding forces greater than those recorded to reflect uncertainties about the historical data and their suitability as a basis for design.

5.0 CONCLUSION

Based on the evaluation described above, the NRC staff concludes the following:

1. The HEC-RAS model an acceptable model to calculate PMF elevation, provided the proper assumptions and calibrations are made.

2. The HEC-RAS model used to calculate the PMF at the BFN site is inadequate. To use the HEC-RAS model to determine the PMF at the BFN site, TVA should perform the following:
   - Model the Cherokee, Boone, Melton Hill, and Douglas Dams to fail during the PMF,
   - Calibrate the HEC-RAS model consistent with the method used in the 2014 WBN LAR, and
   - Model the upstream tributary flows or justify why this is not necessary.

   The calibration and validation of the model should be completed according to NRC guidelines, Reference 4 and follow NRC requirement, 10 CFR Part 50, Appendix A, General Design Criterion 2-Design bases for protection against natural phenomena.

3. Since the model is inadequate and the re-calculated flood elevation may change after model revisions, NRC staff cannot evaluate the significance of the potentially degraded condition at BNF at this time.

6.0 POTENTIAL OUTCOME PATHS

- Immediate Implications: Upon receiving the conclusions of this TIA, the licensee would be expected to enter the issue into their corrective action program.

- Generic Implications: Resolution of this issue does not warrant the issuance of a generic communication, as the issue is licensee-specific.

- Backfit Considerations: Resolution of this issue does not constitute a backfit because it does not involve a new or different position from a previously applicable staff position.

7.0 REFERENCES

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3. Garrison, J.M., Granju, J. P. and Price, and J. T. "Unsteaday Flow Simulation in Rivers and Reservoirs," Journal of Hydraulics Division, Volume 95, No. HY5, by American Society of Civil Engineers. September 1969.
4. NUREG/CR, 7046. "Design-Basis Flood Estimation for Site Characterization at nuclear Power Plants in the USA," published in November, 2011.
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6. Nuclear Regulatory Commission, (NRC). Watts Bar nuclear Plant, Unit 1 - Issuance of Amendment to Revise Updated Final Safety Analysis Report Regarding Changes to Hydrology Analysis (TAC NO. ME9130). january 28, 2015.
7. Tennessee Valley Authority, (TVA). EDMS Verification Package for LER 50-259_2013-001-01, provided in TVA's Certrec IMS website. 2013.
8. Licensee Event Report 50-259 submitted to NRC. 2012.

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