UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

December 4, 2015

Vice President, Operations
Entergy Operations, Inc.
Grand Gulf Nuclear Station
P.O. Box 756
Port Gibson, MS 39150

SUBJECT: GRAND GULF NUCLEAR STATION, UNIT 1 – SUPPLEMENT TO STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NO. MF1102)

Dear Sir or Madam:

The purpose of this letter is to transmit a supplement to the U.S. Nuclear Regulatory Commission (NRC) staff's assessment for Grand Gulf Nuclear Station, Unit 1 (Grand Gulf) reevaluated flood hazard information that was issued to you by letter dated November 25, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14323A019). The supplement updates the original staff assessment to address changes in the NRC's approach to the steps following the review of the flood hazard reevaluations as directed by the Commission. The letter also addresses the next steps associated with the mitigation strategies assessment with respect to the reevaluated flood hazards.

By letter dated March 12, 2012 (ADAMS Accession No. ML12053A340), the NRC issued a request for information pursuant to Title 10 of the *Code of Federal Regulations*, Section 50.54(f) (hereafter referred to as the 50.54(f) letter). The request was issued as part of implementing lessons learned from the accident at the Fukushima Dai-ichi nuclear power plant. Enclosure 2 to the 50.54(f) letter requested licensees to reevaluate flood-causing mechanisms using present-day methodologies and guidance. By letter dated March 11, 2013 (ADAMS Accession No. ML13071A457), Entergy Operations, Inc. (the licensee) responded to this request for Grand Gulf. In response to NRC staff questions, this response was supplemented by letter dated January 9, 2014 (ADAMS Accession No. ML14014A277). The NRC staff has completed its review of the information provided, as documented in the staff assessment and the enclosed supplement to the staff assessment. This closes out the NRC's efforts associated with CAC No. MF1102.

The enclosed supplement to the NRC staff assessment updates the NRC staff's conclusions in accordance with the flood hazard reevaluation approach described in NRC letter dated September 1, 2015 (ADAMS Accession No. ML15174A257), concerning the coordination of requests for information regarding flooding hazard reevaluations and mitigating strategies for beyond-design-basis external events. This letter describes the changes in the NRC's approach to the flood hazard reevaluations that were approved by the Commission in its Staff Requirements Memorandum (ADAMS Accession No. ML15209A682) to COMSECY-15-0019 (ADAMS Accession No. ML15153A104) that described the NRC's mitigating strategies and flooding hazard reevaluation action plan.

As documented in the staff assessment and the enclosed supplement, the NRC staff has concluded that the licensee's reevaluated flood hazard information is suitable for the assessment of mitigation strategies developed in response to Order EA-12-049 (i.e., defines the mitigating strategies flood hazard information described in guidance documents currently being finalized by the industry and NRC staff) for Grand Gulf. Further, the licensee's reevaluated flood hazard information is suitable for other assessments associated with Near-Term Task Force Recommendation 2.1 "Flooding."

The reevaluated flood hazard results for local intense precipitation, streams and rivers, and dam failure were not bounded by the current design-basis flood hazard. In order to complete its response to Enclosure 2 to the 50.54(f) letter, the licensee is expected to submit a revised integrated assessment or a focused evaluation(s), as appropriate, to address these reevaluated flood hazards, as described in the NRC's September 1, 2015, letter.

If there are any questions, please contact me at (301) 415-2915 or Victor.Hall@nrc.gov.

Sincerely,

Victor E. Hall, Senior Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket No.: 50-416

Enclosure:
Supplement to Staff Assessment of Flood Hazard Reevaluation Report

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SUPPLEMENT TO

STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO FLOODING HAZARD REEVALUATION REPORT

NEAR-TERM TASK FORCE RECOMMENDATION 2.1

RELATED TO THE FUKUSHIMA DAI-ICHI NUCLEAR POWER PLANT ACCIDENT

GRAND GULF NUCLEAR STATION, UNIT 1

DOCKET NO. 50-416

1.0 INTRODUCTION

This document is a supplement to the U.S. Nuclear Regulatory Commission (NRC) staff assessment that was transmitted by letter dated April 16, 2015 (NRC, 2014b), for Grand Gulf Nuclear Station (Grand Gulf, GGNS), Unit 1. With the exceptions of Table 3.1-1 and the Reference section, this supplement only contains the sections that were changed to resolve the open item and reflect the changes in the NRC's approach to the flood hazard reevaluations that were approved by the Commission in its Staff Requirements Memorandum (SRM) (NRC, 2015a) to COMSECY-15-0019 (NRC, 2015b), which described the NRC's mitigating strategies and flooding hazard reevaluation action plan. Table 3.1-1 at the end of the supplement is copied from the staff assessment for convenience. Instead of repeating the Reference section in its entirety, only the additions to the list of references are included in the supplement.

2.0 REGULATORY BACKGROUND

2.1 Applicable Regulatory Requirements

There are no changes or updates to this section of the NRC staff assessment.

2.2 Enclosure 2 to the 50.54(f) Letter

By letter dated March 12, 2012 (NRC, 2012a) the NRC issued a request for information Pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f) (hereafter referred to as the 50.54(f) letter). The 50.54(f) letter requests all power reactor licensees and construction permit holders reevaluate all external flood-causing mechanisms at each site. The reevaluation should apply present-day methods and regulatory guidance that are used by the NRC staff to conduct early site permit (ESP) and combined license (COL) reviews. This includes current techniques, software, and methods used in present-day standard engineering practice. If the reevaluated flood-causing mechanisms are not bounded by the current plant design basis flood hazard, an integrated assessment may be necessary.

2.2.1 Flood-Causing Mechanisms

There are no changes or updates to this section of the NRC staff assessment.

2.2.2 Associated Effects

There are no changes or updates to this section of the NRC staff assessment.

2.2.3 Combined Effect Flood

There are no changes or updates to this section of the NRC staff assessment.

2.2.4 Flood Event Duration

There are no changes or updates to this section of the NRC staff assessment.

2.2.5 Actions Following the Flooding Hazard Reevaluation Report (FHRR)

For the sites where the reevaluated flood hazard is not bounded by the current design-basis flood hazard for all flood-causing mechanisms, the 50.54(f) letter requests licensees and construction permit holders to:

- Submit an Interim Action Plan with the FHRR documenting actions planned or already taken to address the reevaluated hazard

- Perform an integrated assessment subsequent to the FHRR to: (a) evaluate the effectiveness of the current licensing basis (i.e., flood protection and mitigation systems); (b) identify plant-specific vulnerabilities; and (c) assess the effectiveness of existing or planned systems and procedures for protecting against and mitigating consequences of flooding for the flood event duration

After issuance of the 50.54(f) letter the NRC changed the approach to the steps following the review of the flood hazard reevaluations as directed by the Commission to permit use of focused evaluations as an alternative to an integrated assessment. The NRC letter dated September 1, 2015 (NRC, 2015c) describes the changes in the NRC's approach to the flood hazard reevaluations.

If the reevaluated flood hazard is bounded by the current design-basis flood hazard for all flood-causing mechanisms at the site, licensees are not required to perform an integrated assessment or a focused evaluation at this time.

3.0 TECHNICAL EVALUATION

There are no changes or updates to this section of the NRC staff assessment.

3.1 Site Information

There are no changes or updates to this section of the NRC staff assessment.

3.2 Local Intense Precipitation and Associated Site Drainage

The licensee reported in its FHRR that the reevaluated flood hazard, including associated effects of debris and sedimentation, but no wind effects, for local intense precipitation (LIP) is 133.7 ft (40.75 m). This flood-causing mechanism is described in the licensee's current design-basis presented in the GGNS, Unit 1 Updated Final Safety Analysis Report (UFSAR) (GGNS, 2012). The current design-basis hazard for the LIP and associated site drainage hazard is 133.25 ft (40.61 m).

The NRC staff requested additional information from the licensee to supplement the FHRR (NRC, 2013c). The licensee provided the additional information by letter dated January 9, 2014 (Mulligan, 2014), which is discussed below.

The NRC staff reviewed the LIP and associated site drainage, including associated effects, against the relevant regulatory criteria based on present-day methodologies and regulatory guidance.

The licensee's reevaluation included an estimation of the maximum water surface elevation from LIP and site drainage for GGNS. Eleven external doors to the Control Building, the Diesel Generator Building, and the Standby Service Water pump houses were identified by the licensee as potential sources of leakage if the water level exceeds 133.0 ft (40.5 m) National Geodetic Vertical Datum of 1929 (NGVD29). In addition, equipment and switchgear for each of the two standby service water basins were considered in the reevaluation. In its FHRR the licensee provided time-series plots of the water elevations during a LIP event for each of the safety-related features mentioned above.

The licensee reported a probable maximum precipitation (PMP) depth of 19.3 in (49.0 cm) in 1 hour with 6.2 in (15.7 cm) in the first 5 minutes and a 6-hour PMP depth of 31.4 in (79.8 cm). The NRC staff previously reviewed the PMP used in the reevaluation in NUREG-1840 (NRC, 2006) as part of its review of the Grand Gulf ESP Application (SERI, 2005). The Grand Gulf ESP site is adjacent to the existing GGNS site. In NUREG-1840, the NRC staff determined the PMP was based on confirmation that all available historical precipitation records for Mississippi and Louisiana since the publication of National Oceanic and Atmospheric Administration (NOAA) Hydrometeorological Reports (HMRs) No. 51 (NOAA, 1978) and 52 (NOAA, 1982) do not exceed the PMP values and are applicable for the estimation of the PMP on the Mississippi River basin and surrounding areas. The NRC staff reviewed its earlier determination and noted that neither the present standard methods nor values associated with estimating the PMP have changed since the NRC staff's ESP review.

The NRC staff notes that a reasonable estimate of the site's LIP PMP is the application of an appropriate NOAA HMR estimate for any rainfall duration used in NUREG/CR-7046, regardless of temporal distribution of the rainfall. The licensee obtained 1-sq. mile PMP depths for durations ranging between 5-minutes and 6-hours using HMR-51 and HMR-52. Therefore, the NRC staff confirmed that the licensee selected appropriate rainfall rate values to satisfy the 50.54(f) information request.

The licensee estimated the LIP flood elevations with a commercial, spatially distributed, two-dimensional hydrologic and hydraulic model, FLO-2D (FLO-2D, 2009), designed to simulate overland flow over complex terrain. A digital terrain model of the GGNS site was used as input to FLO-2D to define surface elevations of a 20 by 20-ft (6.1 by 6.1-m) grid over the model domain. The licensee stated in the response to request for additional information (RAI) 3.2-4 that the digital terrain model was based on a topographic survey that was required to meet overall vertical and horizontal accuracy standards with critical structures and locations for flooding surveyed with a vertical accuracy of within 0.1 ft (0.03 m) (Mulligan, 2014). The FLO-2D internal interpolation methods were used to assign an elevation to each grid cell. The licensee stated that interpolated grid elevations were spot checked against the survey elevations at all critical points, and adjusted as necessary.

Additional controls on overland flow were prescribed for buildings, channels, culverts, and a vehicle barrier system (VBS) that surrounds all safety-related systems, structures, and components at GGNS. The ground surface enclosed within the VBS was assumed to be completely impervious. Buildings were represented as obstructions to flow. Figure 3.2-1 shows the drainage ditches and Stream B represented as channels in the FLO-2D model. Six culverts, including Culvert 1, which discharges to Stream B beneath the plant access road, were considered not to have failed completely. The licensee represented the VBS using a levee structure feature of FLO-2D and considered two types of openings in the barriers.

The licensee stated in its FHRR that, in accordance with NUREG/CR-7046, the culverts were assumed to be 50 percent blocked. The licensee used CulvertMaster (Bentley, 2005) to develop depth-discharge relationships for the following onsite culverts:

- Culvert 9A: three 4-ft (1.2-m) diameter culverts that discharge into Stream A,
- Culvert 11: a 6-ft-wide (1.8-m-wide) by 4-ft-high (1.2-m-high) box culvert at the northwest end of the Switchyard, and
- Culvert 8A: a 4-ft-diameter (1.2-m-diameter) culvert at the southwest end of the Switchyard.

The licensee stated in response to RAI 3.2-2 that the expected blocking mechanism is accumulation of small debris (e.g., leaf litter) on the face of the security screen, which would reduce the effective flow capacity but would not change the area of the opening or the invert elevations (Mulligan, 2014). The licensee represented this type of blockage by reducing the discharge by 50 percent at each point on the depth-discharge relationship for each culvert. The licensee used the depth-discharge relationships as input to the FLO-2D model.

The NRC staff noted that Culvert 1, which is a 15-ft-diameter (4.6-m-diameter) culvert, was not modeled by CulvertMaster, but represented directly in FLO-2D as a 10.6-ft (3.2-m) diameter culvert with the upstream and downstream culvert invert elevations increased 4.4 ft (1.3 m) above the actual invert elevation. The NRC staff determined that this modeling approach was acceptable, as the reduced culvert cross section from debris blocking, which is highly unlikely for a large-size culvert, results in conservatively high onsite flood level estimates.

The VBS was represented as a levee in the FLO-2D model and the licensee considered two types of openings in the barriers. The licensee assumed that small 0.6 ft-diameter (0.2 m diameter) VBS openings were completely blocked. The licensee modeled larger openings in the VBS using hydraulic structures in the FLO-2D model, assuming those openings to be 30 percent blocked by debris on security screens. Depth-discharge relationships for VBS openings were developed in CulvertMaster. For FLO-2D input, the discharge associated with the "depth" (difference in water-surface elevation inside and outside the VBS) at each VBS opening was reduced by 30 percent.

The partial blockage assumptions for the culverts and VBS are reasonable assumptions because the licensee has established procedures to verify that the culvert and VBS openings are clear of debris (NRC, 2015d). Visual inspections of the culverts are described in the licensee's surveillance procedure 06- TE-1000-V-0001, Revision 101, "CURVERT NO. 1 EMBANKMENT STABILITY/SURVEY." Visual inspections of the vehicle barrier openings are described in the licensee's off-normal event procedure 05-1-02-VI-2, Revision 128, "HURRICANES, TORNADOES, AND SEVERE WEATHER." Both of these procedures describe how the licensee will implement periodic surveillances, as well as needed surveillances before and after intense precipitation events.

The NRC staff reviewed the FLO-2D model input and output related to the LIP runoff analyses provided by the licensee. The NRC staff identified multiple issues with the LIP runoff modelling. In the FHRR, the licensee stated that buildings were represented as obstructions to flow, but provided no description of how precipitation falling on building roofs was represented in the model. The NRC staff found that, in the licensee's FLO-2D model, precipitation falling on roofs did not enter the overland flow domain on the ground. The NRC staff also identified additional modeling issues related to the LIP FLO-2D simulations, such as inaccurate water budgets and unrealistic stage hydrographs (e.g., FHRR Figures 3.1-9, 3.1-10, 3.1-14, and 3.1-16), which show high flood stages even after the ending of the postulated PMP event. Also, the NRC staff was unable to verify the accuracy of water budgets and long-tails on the simulated stage hydrographs presented in FHRR Figures 3.1-9, 3.1-10, 3.1-14, and 3.1-16. FHRR Section 3.1.3 states that significant debris loading and transportation on LIP flooding is not a hazard due to the relatively low velocity and depth of LIP flood waters in the plant site, in addition to the lack of natural debris sources onsite. The NRC staff determined the effect of wind on LIP flood is not applicable due to the short fetch length and shallow inundation depth for flooding from LIP.

The licensee indicated that the reevaluated LIP flood elevation exceeds the current design-basis. The NRC staff confirmed the licensee's conclusion that the reevaluated flood hazard for LIP and associated site drainage is not bounded by the current design-basis flood hazard. Therefore, the licensee is expected to submit a focused evaluation confirming the capability of flood protection and available physical margin consistent with the process and guidance discussed in COMSECY-150019 (NRC, 2015a). In addition, the modelling issues that are discussed above should be addressed in the focused evaluation, if the licensee uses the same FL0-2D model in its focused evaluation.

3.3 <u>Streams and Rivers</u>

The licensee reported in its FHRR that the reevaluated hazard without wind effects for site flooding from Stream A that bounds other stream and river floods is 132.1 ft (40.26 m). This flood-causing mechanism is described in the licensee's current design-basis. The corresponding current design-basis hazard for site flooding from streams and rivers (without wind effect) is 128.9 ft (39.29 m).

FHRR Section 3.2 discusses four sources of probable maximum flood on streams and rivers: Mississippi River, Bayou Pierre, Stream A, and Stream B. The following describes the NRC staff's review of site flooding from streams and rivers, including associated effects, against the relevant regulatory criteria based on present-day methodologies and regulatory guidance.

Mississippi River

The licensee evaluated the probable maximum flood (PMF) on the Mississippi River by first estimating the PMF based on a literature review and engineering judgment. Then, the licensee developed cross sections for the Hydrologic Engineering Center's River Analysis System (HEC- RAS) (USACE, 2010) steady flow model, and set up the model for the river reach extending from 29 miles (47 km) upstream to 26 miles (42 km) downstream from the site. The licensee calibrated the HEC-RAS model using the U.S. Army Corps of Engineers (USACE) design project flow and elevation at the GGNS site by adjusting the Manning's n values and boundary friction slopes on both upstream and downstream. Finally, the licensee estimated PMF elevations on the river using HEC-RAS with the UFSAR basin PMF rate of 8,250,000 ft^3/s (234,000 m^3/s) (GGNS, 2012). The licensee also provided the state-discharge values which were used by the NRC staff to develop a rating curve for the site (see Figure 3.3-2). Based on the reevaluation, the licensee obtained the Mississippi River PMF elevation of 106.2 ft (32.37 m) NGVD29 which is far below the plant grade.

To estimate the wind effects on the Mississippi River PMF (see FHRR Section 3.9), the licensee first estimated the longest straight line fetch on the Mississippi River of 63.3 miles (102 km) and determined a 2-yr return period wind speed of 45.2 mi/h (72.7 km/h) using a fitting of the Gumbel Distribution with historical wind data at the Tallulah Vicksburg Regional Airport. The licensee then estimated that the deepest water wave height for the Mississippi River is 6.3 ft (1.92 m) with a wave period of 5.1 seconds. Using the General Engineering Module Automated Coastal Engineering System v4.3 Computer Program, the licensee calculated the wind wave effect to be 2.2 ft (0.67 m) and the wave runup height to be 14.1 ft (4.30 m). Finally, the licensee estimated the flood level from the combined effect of PMF and wave action to be 122.5 ft (37.34 m), which is far below the plant grade.

This result indicates that the levees at elevation 103 ft (31.4 m) on the west bank of the river are overtopped during the PMF event, resulting in lowering actual river flood elevations on the river compared to the licensee's non-overtopping estimates. Flooding in the Mississippi River was also addressed in NUREG-1840, where the NRC staff concluded that the GGNS plant site is above the elevation attained by the PMF in the Mississippi River and that flooding of the Mississippi River is not a controlling flood hazard for the GGNS site.

Bayou Pierre

The licensee evaluated the PMF on Bayou Pierre by calculating the basin PMP using HMR 51 (NOAA, 1978) and HMR 52 (NOAA, 1982), simulating the basin outflows in the vicinity of the site using HEC-HMS (USACE, 2000), and estimating the PMF elevation at the river using a HEC-RAS unsteady flow option.

The licensee calibrated and verified the model using observed United States Geological Survey (USGS) stream flow data and nonlinearity adjustments to the subbasin unit hydrographs. The FHRR reported a 72-hour PMP value of 36.3 in. (92.2 cm) for the Bayou Pierre Basin, which has an area of 1,005 mi^2 (2,602 km^2). The estimated PMF elevation at the Bayou Pierre in the vicinity of the site is 130.7 ft (39.84 m). This reevaluated flood elevation is lower than the plant grade. Flooding on the Bayou Pierre was not addressed in the GGNS, Unit 1 UFSAR (GGNS, 2012) or the Grand Gulf ESP application (SERI, 2005), indicating no design-basis values on Bayou Pierre. The licensee stated that the GGNS site is protected from Bayou Pierre flooding by a 175 ft (53.34 m) NGDV29 watershed divide between the river and the site. The NRC staff confirmed this divide on a topographic map and concurs with the licensee's conclusion that the GGNS site cannot be inundated from flood waters originating in the Bayou Pierre Basin.

Stream A and B

The licensee evaluated the PMF on Stream A and Stream B (see Figure 3.3-1) by: obtaining the basin PMP values using HMRs 51 (NOAA, 1978) and 52 (NOAA, 1982); simulating basin outlet PMF rates using the Soil Conservation Method programmed in HEC-HMS (USACE, 2000) to simulate basin runoff for ungagged streams and assuming no infiltration or evaporation losses conservatively, and; estimating water elevations associated with the simulated PMF rates using FLO-2D that routes both one-dimensional channel flow and two-dimensional overland flow on the vicinity of the plant site.

The licensee stated that a two-dimensional overland flow model for Streams A and B is necessary to determine the impact of stream PMF events on the GGNS site. The licensee used FLO-2D to simulate water surface elevations for the PMF on Streams A and B. Given the significant role that the hydrologic models perform in the licensee's reevaluation and the need to review the formulation of its complex spatially and temporally distributed input, the NRC staff requested in RAI 3.3-2 that the licensee provide the model input and output files used in the PMF analyses. By letter dated January 9, 2014 (Mulligan, 2014), the licensee provided the requested input and output files for the HEC-HMS and FLO-2D models, which the NRC staff reviewed. The NRC staff noted that the Manning's roughness coefficients used for both channels (0.015 to 0.02) and overland floodplains (0.04 to 0.05) are within the range of values recommended by the FLO-2D User's Manual (FLO-2D, 2009).

The primary inputs to FLO-2D were developed from a digital elevation model, land-use cover maps, and a relationship between land-use cover and surface roughness. The licensee used high-resolution topographic data to determine 50-ft (15 m) grid elevations for FLO-2D. The NRC staff reviewed the grid elevations near the vicinity of the plant site.

The licensee conservatively assumed no losses due to infiltration and assumed that all minor channels, other than Streams A and B, and most culverts near the plant site were non-functional. The licensee made one exception for Culvert No.1, located on Stream B, south of the plant site. Culvert No. 1 is a 15-ft (4.6-m) corrugated metal pipe that runs beneath a GGNS access road. The licensee stated that Stream B in the vicinity of the plant site is lined with concrete to a height of 5 ft (1.5 m) above the channel bottom and with riprap from a height of 5 ft (1.5 m) above the channel bottom to plant grade elevation limiting sources of debris. The licensee also noted that there is an operating procedure to ensure that Culvert No. 1 is free from debris. The NRC staff reviewed the licensee's culvert blocking scenarios and noted that the scenarios follow the guidance in NUREG/CR-7046 (NRC, 2011e).

The licensee reported in its FHRR that the 72-hour PMP value for the combined two stream basins is 53.5 in. (135.89 cm), where the basin areas for Streams A and B are 2.8-mi^2 (7.2 km^2) and 0.6-mi^2 (1.55 km^2), respectively. The estimated PMF peak flow rates for Streams A and B are 18,600 and 6000 ft^3/s (527 and 170 m^3/s), respectively, while the corresponding flood elevations with wind effects are 132.5 ft (40.4 m) and 132.2 ft (40.3 m), respectively (FHRR Section 3.9.2.2).

The NRC staff reviewed the licensee-provided model input and output in terms of volume conservation, area of inundation, and maximum water velocities. The NRC staff observed that the water balance error for the licensee's FLO-2D simulation run was less than 0.02 percent, indicating that the simulation conserved mass. The NRC staff further noted that, although the stream FLO-2D model did not account for the rainfall on building roofs and channel areas as was observed for the LIP FLO-2D model, the propagation error in estimating flood elevations was less than 1 percent in elevation. Finally, the NRC staff examined the model output related to inundation areas, maximum velocities, and numerical instabilities, and found no abnormal features in these model output.

The licensee considered the wind effects on estimating bounding PMF elevation at Stream A (see Table 4.0-1), whereas the design basis PMF elevations on both Stream A and Stream B (Table 3.1-1) do not include wind effects as these floods would not inundate the plant site.

Combined Events

The NRC staff noted that the licensee did not address in its FHRR a combined flooding on the Bayou Pierre basin or a combined flooding event from onsite and basins for Streams A and B. In RAI No. 3.3-3, the NRC staff requested the licensee provide an analysis of the Bayou Pierre flooding considering appropriate combinations of PMP, dam failure, channel migrations and divisions, and land slide blockage, or justify why such events are not plausible or not significant to the site (NRC, 2013c). In response to RAI 3.3-3 (Mulligan, 2014), the licensee stated that, based on a simple bounding analysis, the combined Bayou Pierre flood event of PMF and dam failure will not overtop the Bayou Pierre watershed divide and reach the GGNS site. The licensee also concluded that the potential channel migration, diversion, and landslide in Bayou Pierre is not considered to be significant enough to create onsite floods based on a review of the USGS topography data. The licensee further concluded that landslides on the Bayou Pierre are not considered a credible source of flooding impact to the site.

The NRC staff noted that the northern portion of the onsite drainage channel is connected to

Stream A while the southern portion of the onsite drainage is linked to Stream B. The NRC staff also noted that the estimated PMF levels on both streams which are lower than the plant grade are higher than the invert elevations for onsite drainage channel outlets. Because of these site configurations and a PMP event could be applied to all three basins, the NRC staff determined that a combined flood from onsite and basins for Stream A and Stream B could be plausible and more severe than individual floods. In RAI 3.3-4, the NRC staff requested the licensee to provide an analysis of a combined flooding event from onsite and drainage basins for Stream A and Stream B, or to justify why the combined flooding event is not plausible using appropriate topographical and structural data (NRC, 2013c). In response to RAI 3.3-4 (Mulligan, 2014), the licensee described that the PMF determined for Streams A and B includes the site as a contributory area, but with a shorter runoff lag time because (1) the onsite area is mostly paved and (2) the reach of the onsite drainage channel is relatively shorter than those of the streams. The licensee noted that the maximum water surface elevations within the plant site resulting from LIP are not expected to be influenced by floods on Streams A and B. The NRC staff reviewed the licensee's model inputs and outputs related to the Streams A and B analyses and agreed with the licensee's statement that the onsite LIP flood is not influenced by PMFs on Stream A and B mainly due to the difference of peak discharge arrival times at the basin outlets.

Summary

The NRC staff determined that the general methods described in the licensee's FHRR are consistent with present-day methods. The NRC staff determined that, among four stream and river flooding scenarios, the PMF with wind effects on Stream A is bounding and exceeds the corresponding design basis flood elevation. The NRC staff confirmed that the reevaluated flood hazard for streams and rivers is not bounded by the current design-basis flood hazard. Therefore, the licensee is expected to submit a focused evaluation confirming the capability of flood protection and available physical margin or a revised integrated assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015a).

3.4 Failure of Dams and Onsite Water Control/Storage Structures

The licensee reported in its FHRR that the reevaluated hazard for site flooding due to failure of dams on the Mississippi River and onsite water control/storage structures results in a stillwater elevation of 117.4 ft (35.78 m). This flood-causing mechanism is described in the licensee's current design-basis, where the licensee screened out upstream dam failure flooding on the Mississippi River as a plausible flood causing mechanism to the site.

The NRC staff reviewed the licensee's reevaluation of site flooding from failure of upstream dams and onsite water control/storage structures, including associated effects, against the relevant regulatory criteria based on present-day methodologies and regulatory guidance. The licensee did not identify any dams on the Streams A and B basins. The NRC staff confirmed this statement based on the review of information from the latest version of the National Inventory of Dams (NID) Database (USACE, 2013). Correspondingly, the NRC staff focused its review on Mississippi River and Bayou Pierre.

Mississippi River

The FHRR stated that there are no dams on the Mississippi River within 100 river miles (161 river km) upstream of the site. In the Grand Gulf, Units 2 and 3 ESP (SERI, 2005), the licensee performed a dam failure flood analysis which was adopted in the FHRR. This dam failure flood analysis identified about 300 significant dams in the Mississippi River basin. To simplify the analysis, the licensee chose the largest dam nearest to the site, the Kentucky Dam about 160 miles (260 km) upstream, and estimated the peak breach outflow to be 3.92 million ft^3/s (0.111 million m^3/s) using the dam breach peak flow equation by Fread (1991). The licensee then added this breach outflow to the Mississippi River PMF rate of 8.25 million ft^3/s (0.234 million m^3/s) to determine a combined flood rate of 12.17 million ft^3/s (0.345 million m^3/s), resulting in a HEC-RAS-based flood stillwater elevation of 117.4 ft (35.78 m) in the vicinity of the Mississippi River near the GGNS site. In this dam failure reevaluation, the licensee did not consider wave effects "due to the sufficient margin indicated by the initial conservative analysis" (FHRR Section 3.3.3), as well as the effect of overbank capacity along the Mississippi River.

As part of its review of the licensee's dam failure flood analysis, the NRC staff performed a simple bounding dam failure flood analysis using multiple dam failures on the Lower Mississippi River under the hierarchical hazard analysis approach. The objective of this simple bounding analysis was to evaluate the sensitivity of hypothetical multiple upstream dam failures on the site flooding. The NRC staff identified from the updated NID Database (NID, 2013) that there are over 15,000 dams within the entire basin area of over 1.2 million square miles (3.1 million km^2). Noting that the simultaneous or sequential failure of all dams within the entire basin was not plausible, the NRC staff considered only the Lower Mississippi River basin which extends from the junction of Mississippi River and Tennessee River to the GGNS plant site, having an area of approximately 60,000 square miles (155,000 km^2) and in which about 3,700 dams are located. For these selected dams, the NRC staff calculated the breach peak outflow attenuated to the site using the Froehlich breach peak equation (1995) and the flow attenuation equation by the U.S. Bureau of Reclamation (1982). The sum of the attenuated breach peak flows for the selected dams is 3.384 million ft^3/s (0.812 million m^3/s). Summing this dam breach peak flow and a PMF discharge of 8.25 million ft^3/s (21.36 million km^2), the NRC staff obtained a combined peak flow rate at the site of 11.634 million ft^3/s (48.46 million m^3/s). Using the rating curve in Figure 3.3-2, the NRC staff obtained a flood elevation for the combined event of PMF and dam failure of 112.8 ft (34.38 m), which is lower than the licensee's estimate.

The key difference between the licensee's and NRC staff's dam failure scenarios is that the former uses a single dam failure without attenuation along the downstream river, whereas the latter considers multiple dam failures with attenuation along the river reach. However, the resulting dam breach flood stillwater elevations in the vicinity of the river at the site are both well below the plant grade.

The licensee concluded in its FHRR in Section 3.9.1.1, that floods caused by seismic dam failures are bounded by the PMF with coincident dam failure on the Mississippi River at the plant site. Moreover, the levees at elevations ranging 101 to 103 ft (30.8 to 31.4 m) on the west bank of the Mississippi River are overtopped during the PMF, upstream dam failures, or their combinations, result in diverting significant amount of river flooding away from the plant site. Therefore, the NRC staff agrees with the licensee's conclusion the Mississippi River flooding caused by either hydrologic or seismic dam failure, or their combined events with other plausible flood causing mechanisms with associated effects will not inundate the plant site.

Bayou Pierre

The NRC staff also performed a simple bounding dam failure flood analysis on the Bayou Pierre. The NRC staff identified from the NID Database (USACE, 2013) a total of 59 dams within the Bayou Pierre basin as shown on Figure 3.4-1. The total storage volume of these dams is 34,149 ac-ft (42.1 km3), and the maximum storage volume of 15,489 ac-ft (19.1 km3) for the Lake Calling Panther Reservoir on the eastern upstream of the basin. The NRC staff assumed that all dams fail and discharge water to the basin outlet simultaneously without loss. The NRC staff estimated the peak dam failure outflow using the bounding breach peak flow equation by Froehlich (1995). The resulting sum of the peak breach outflows was 641,853 ft^3/s (18,175 m^3/s). Adding the peak breach flow to the basin PMF rate, the NRC staff obtained a total combined flood rate of approximately 1,376,000 ft^3/s (38,964 m^3/s), which was a significant increase compared to the PMF-only rate.

Therefore, in RAI 3.3-3, the NRC staff requested the licensee to provide an analysis of a combined event of PMF, dam failure, and other applicable flood causing mechanisms, or provide a justification if such event is not plausible. In response to this RAI, the licensee stated that Bayou Pierre is not anticipated to overflow the watershed divide between its basin and the site. The NRC staff reviewed the relevant information (see discussion in Section 3.9, below) and agrees with the licensee's conclusion that flooding from Bayou Pierre would not overflow the watershed divide separating it from the GGNS site.

Summary

The licensee analyzed the dam failure flooding scenarios on the Mississippi River and Bayou Pierre. The licensee also considered a combined event of PMF and dam failure on the Mississippi River. From the result of these analyses, the licensee concluded that the flooding caused by any dam failure or its combined event would not inundate the plant site. The NRC staff performed a confirmatory analysis of the multiple dam failure flooding on the Lower Mississippi River basin and confirmed the licensee's conclusion that any dam failure flooding and it's combined and associated effect flooding on the Mississippi River would not inundate the plant site. The NRC staff identified no onsite water control or storage structures that could cause potential dam failure flooding to the plant site.

The NRC staff confirmed that the reevaluated hazard for flooding from the failure of dams and onsite water control/storage structures is not bounded by the current design-basis flood hazard. Therefore, the licensee is expected to submit a focused evaluation confirming the capability of flood protection and available physical margin or a revised integrated assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015a).

3.5 Storm Surge

There are no changes or updates to this section of the NRC staff assessment.

3.6 Seiche

There are no changes or updates to this section of the NRC staff assessment.

3.7 Tsunami

There are no changes or updates to this section of the NRC staff assessment.

3.8 Ice-Induced Flooding

There are no changes or updates to this section of the NRC staff assessment.

3.9 Channel Migrations or Diversions

There are no changes or updates to this section of the NRC staff assessment.

4.0 REEVALUATED FLOOD HEIGHT, EVENT DURATION AND ASSOCIATED EFFECTS FOR HAZARDS NOT BOUNDED BY THE CURRENT DESIGN-BASIS

The NRC staff confirms that the reevaluated hazard results for LIP, streams and rivers, and dam failure are not bounded by the current design-basis flood hazard. Therefore, the NRC staff anticipates that the licensee will perform additional assessments (i.e., integrated assessment or focused evaluation) of plant response for GGNS, as described in NRC letter dated September 1, 2015 (NRC, 2015c). The NRC staff reviewed the following flood hazard parameters needed to perform the additional assessments or evaluations of plant response:

- Flood event duration (see Table 4.0-1), including warning time and intermediate water surface elevations that trigger actions by plant personnel, as defined in JLD-ISG-2012-05

- Flood height and associated effects, as defined in JLD-ISG-2012-05 (see Table 4.0-2)

In Section 3.9 of its FHRR, the licensee addressed plausible combined-effect flooding, including a combined event of PMF and dam failure flooding on the Mississippi River. The NRC staff's review of this combined event flooding is addressed in Section 3.4 of this NRC staff assessment. Associated wind effect on the Mississippi River flooding is addressed in Section 3.3. The licensee incorporated wind effects on river and stream PMF estimations, and debris effects on LIP flooding. The NRC staff concluded that other associated effects, including the effects of hydrodynamic loading, erosion and sedimentation, and groundwater ingress are not applicable to this site, and therefore, do not need to be evaluated.

The NRC staff requested, via RAI No. 4.0-1, the licensee to provide the applicable flood event duration parameters associated with mechanisms that were not bound by the current design-basis. The relevant flood duration parameters include the warning time the site will have to prepare for the event, the period of time the site is inundated, and the period of time necessary for water to recede off the site for the mechanisms that are not bounded by the current design-basis. The licensee's response, dated January 9, 2014 (Mulligan, 2014), states that the site is only inundated by LIP events and that the LIP flooding, which is the controlling flood mechanism for GGNS Unit 1, exceeds the design-basis.

In Figures 3.1-6 through 3.1-19 of its FHRR, the licensee indicated that the maximum LIP inundation depth would occur in front of the "OCT5" door, which is located between the Unit 1 and 2 Reactor Buildings and leads into the Control Building. In addition to the flood warning time provided by the response to RAI No. 4.0-1, the NRC staff determined the following LIP flood duration parameters based on the simulated LIP hydrograph provided by the licensee (see Figure 3.1-16 in the FHRR):

- Flood warning time of 24 hours is used from prediction of over 12 inches (30.5 cm) of rain from the National Weather Service, and site preparation is governed by the Off-Normal Event Procedure 05-1-02-VI-2 "Hurricanes, Tornados and Severe Weather.
- Flood inundation duration at the "OCT5" door is estimated to be over 15 hours for the 6-hour PMP.
- Flood recession duration at the same location is over 14 hours for the 6-hour PMP.

Flooding on streams and rivers, upstream dam failures, and their combined events are at or below the plant grade of 132.5 ft (70.9 m). As a result, the licensee did not provide flood event duration parameters as part of the RAI response.

Based upon the preceding analysis, NRC staff confirms that the reevaluated flood hazard information defined in the sections above is appropriate input to other assessments or evaluations associated with Near-Term Task Force Recommendations, including the assessment of mitigation strategies developed in response to Order EA-12-049 (i.e., defines the mitigating strategies flood hazard information described in guidance documents currently being finalized by the industry and NRC staff).

5.0 CONCLUSION

The NRC staff has reviewed the information provided for the reevaluated flood-causing mechanisms for GGNS, Unit 1. Based on its review, the NRC staff concludes that the licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance used by the NRC staff in connection with ESP and COL reviews.

Based on the preceding analysis, the NRC staff confirmed that the licensee responded appropriately to Enclosure 2, Required Response 2, of the 50.54(f) letter. In reaching this determination, the NRC staff confirmed the licensee's conclusions that (a) the reevaluated flood hazard results for local intense precipitation, streams and rivers, and dam failure are not bound by the current design-basis flood hazard, (b) additional assessments of plant response will be performed for the local intense precipitation, streams and rivers and dam fauliure flood-causing mechanisms, and (c) the reevaluated flood-causing mechanism information is appropriate input to additional assessments or evaluations of plant response, as described in the 50.54(f) letter and COMSECY-15-0019 (NRC, 2015b), including the assessment of mitigation strategies developed in response to Order EA-12-049 (i.e., defines the mitigating strategies flood hazard information described in guidance documents currently being finalized by the industry and NRC staff).

The NRC staff has no additional information needs at this time with respect to the FHRR.

6.0 REFERENCES

U.S. Nuclear Regulatory Commission (NRC) Documents and Publications:

NRC (U.S. Nuclear Regulatory Commission), 2014b, letter from Victor E. Hall, , to Vice President Operations, Entergy Operations, Inc., "Grand Gulf Nuclear Station, Unit 1 – Staff Assessment of Response to 10 CFR 50.54(f) Information Request- Flood-Causing Mechanism Reevaluation (TAC NO. MF1102)", dated November 25, 2014 ADAMS Accession No. ML14323A019.

NRC (U.S. Nuclear Regulatory Commission), 2015a, SRM – COMSECY-15-0019 – Closure Plan for the Reevaluation of Flooding Hazards for Operating Nuclear Power Plants," COMSECY-15-0019, July 28, 2015, ADAMS Accession No. ML15209A682.

NRC (U.S. Nuclear Regulatory Commission), 2015b, "Closure Plan for the Reevaluation of Flooding Hazards for Operating Nuclear Power Plants," COMSECY-15-0019, June 30, 2015, ADAMS Accession No. ML15153A104.

NRC (U.S. Nuclear Regulatory Commission), 2015c, letter from William M. Dean, Director, to Power Reactor Licensees, "Coordination of Requests for Information Regarding Flooding Hazard Reevaluations and Mitigating Strategies for Beyond-Design-Basis External Events", dated September 1, 2015, ADAMS Accession No. ML15174A257.

NRC (U.S. Nuclear Regulatory Commission), 2015d, memo from Michael L Marshall, to Mohamed K. Shams, "Summary of Conference Call Confirming Staff Understanding of Basis for Closing Open Item in the Grand Gulf Nuclear Station, Unit 1 Reevaluated Flood Hazard Staff Assessment of Response to 10 CFR 50.54(f) Information Request – Flood-Causing Mechanism Reevaluation", dated November 24, 2015, ADAMS Accession No. ML15324A086.

Codes and Standards

There are no additions to the references in this section.

Other References:

There are no additions to the references in this section.

Table 3.1-1: Design-Basis (DB) Flood Hazard

Flooding Mechanism	DB Still-Water Level ft (m)	DB Associated Effects ft (m)	Current DB Flood Level ft (m)	Reference
Local Intense Precipitation and Associated Drainage	133.25 (40.61)	Not Applicable	133.25 (40.61)	FHRR 2.3.1
Streams and Rivers • Mississippi River • Stream A • Stream B	 103 (31.39) 128.9 (39.30) 132.8 (40.48)	 5.8 (1.8) Not Considered Not Considered	 108.8 (31.39) 128.9 (39.30) 132.8 (40.48)	FHRR 2.3.1
Failure of Dams and Onsite Water Control/Storage Structures	No Impact Identified	Not Discussed	No Impact Identified	FHRR 2.3.1
Storm Surge	No Impact Identified	Not Discussed	No Impact Identified	FHRR 2.3.1
Seiche	No Impact Identified	Not Discussed	No Impact Identified	FHRR 2.3.1
Tsunami	No Impact Identified	Not Discussed	No Impact Identified	FHRR 2.3.1
Ice-Induced	No Impact Identified	Not Discussed	No Impact Identified	FHRR 2.3.1
Channel Migrations or Diversions	No Impact Identified	Not Discussed	No Impact Identified	FHRR 2.3.1

Note: The GGNS plant grade elevation is 132.5 ft (40.39 m) MSL.

Table 4.0-1: Flood Event Duration (see Figure 2.2-1) for Reevaluated Flood-Causing Mechanisms Not Bounded by the Current Design-Basis.

Flood-Causing Mechanism	Site Preparation for Flood Event	Period of Site Inundation	Recession of Water from Site
Local Intense Precipitation and Associated Drainage (for 6-hour precipitation event) (1)	24 hours (Response to RAI 4.0-1)	Greater than 15 hours	Greater than 14 hours
PMF on Stream A	Not Discussed(2)	Not applicable because site not inundated by the hazard mechanism	
Dam Failure Flooding	Not Discussed(2)	Not applicable because site not inundated by the hazard mechanism	

Notes:

(1) Based on the hydrograph at the door "OCT5" presented by Figure 3.1-16 in the FHRR.

(2) The licensee did not provide this value because Stream A PMF and flooding from dam failures will not inundate the site. Estimated flood levels for Stream A flooding and dam failure flooding on Mississippi River are equal to or less than the plant grade.

Table 4.0-2: Reevaluated Flood-Causing Mechanisms and Associated Effects Hazards Not Bounded by the Current Design-Basis.

Reevaluated Flood-Causing Mechanism	Stillwater Elevation ft(m)	Associated Effects ft (m)	Reevaluated Flood Hazard ft (m)	Reference
LIP and Associated Drainage	133.7 (40.75)	Debris effects on LIP flood are considered but other effects are not applicable	133.7 (40.75)	FHRR Section 3.1
PMF on Stream A	132.1 (40.26)	0.4 (0.12) from wind effects	132.5 (40.39)	FHRR Sections 3.2 and 3.9
Dam Failure Flooding with PMF on Mississippi River	117.4 (35.78)	Not Applicable(2)	117.4 (35.78) without wind effects	FHRR Section 3.3

Notes:

(1) The GGNS plant grade is 132.5 ft (40.4 m).

(2) The licensee noted that additional refinement of dam failure flood analysis including associated effects is not necessary due to the sufficient margin indicated by the initial conservative analysis (FHRR Subsection 3.3.3).

Table 5.0-1: Integrated Assessment Open Items

Deleted

As documented in the staff assessment and the enclosed supplement, the NRC staff has concluded that the licensee's reevaluated flood hazard information is suitable for the assessment of mitigation strategies developed in response to Order EA-12-049 (i.e., defines the mitigating strategies flood hazard information described in guidance documents currently being finalized by the industry and NRC staff) for Grand Gulf. Further, the licensee's reevaluated flood hazard information is suitable for other assessments associated with Near-Term Task Force Recommendation 2.1 "Flooding."

The reevaluated flood hazard results for local intense precipitation, streams and rivers, and dam failure were not bounded by the current design-basis flood hazard. In order to complete its response to Enclosure 2 to the 50.54(f) letter, the licensee is expected to submit a revised integrated assessment or a focused evaluation(s), as appropriate, to address these reevaluated flood hazards, as described in the NRC's September 1, 2015, letter.

If there are any questions, please contact me at (301) 415-2915 or Victor.Hall@nrc.gov.

Sincerely,

/RA/

Victor E. Hall, Senior Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket No.: 50-416

Enclosure:
Supplement to Staff Assessment of Flood
Hazard Reevaluation Report

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