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

November 25, 2014

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 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST -- FLOOD-CAUSING MECHANISM REEVALUATION (TAC NO. MF1102)

Dear Sir or Madam:

By letter dated March 12, 2012, the U.S. Nuclear Regulatory Commission (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 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13071A457), Entergy Operations, Inc. responded to this request for Grand Gulf Nuclear Station, Unit 1. In response to NRC staff questions, this response was supplemented by letter dated January 9, 2014 (ADAMS Accession No. ML14014A277).

The NRC staff has reviewed the information provided and, as documented in the enclosed staff assessment, determined that you provided sufficient information in response to the 50.54(f) letter. Because the reevaluated flood-causing mechanism was not bounded by your current plant-specific design-basis hazard, the NRC staff anticipates submittal of an Integrated Assessment in accordance with Enclosure 2, Required Response 3, of the 50.54(f) letter no more than 2 years from the date you submitted the Flood Hazard Reevaluation Report. In addition, the staff has identified three issues that resulted in Integrated Assessment Open Items. These Integrated Assessment Open Items are documented and explained in the enclosed staff assessment and should be addressed as part of the Integrated Assessment.

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:
Staff Assessment of Flood Hazard
Reevaluation Report

cc w/encl: Distribution via Listserv

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

By letter dated March 12, 2012 (NRC, 2012a), the U.S. Nuclear Regulatory Commission (NRC) issued a request for information to all power reactor licensees and holders of construction permits in active or deferred status, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f) "Conditions of license" (hereafter referred to as the 50.54(f) letter). The request was issued in connection with implementing lessons-learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant as documented in the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident (NRC, 2011b). Recommendation 2.1 in that document recommended that the staff issue orders to all licensees to reevaluate seismic and flooding for their sites against current NRC requirements and guidance. Subsequent Staff Requirements Memoranda associated with Commission Papers SECY-11-0124 (NRC, 2011c) and SECY-11-0137 (NRC, 2011d), directed the NRC staff to issue requests for information to licensees pursuant to 10 CFR 50.54(f).

Enclosure 2 to the 50.54(f) letter requested that licensees reevaluate flood hazards for their respective sites using present-day methods and regulatory guidance used by the NRC staff when reviewing applications for early site permits (ESPs) and combined licenses (COLs). The required response section of Enclosure 2 specified that NRC staff would provide a prioritization plan indicating Flooding Hazard Reevaluation Report (FHRR) deadlines for individual plants. On May 11, 2012, the staff issued its prioritization of the FHRRs (NRC, 2012b).

If the reevaluated hazard for any flood-causing mechanism is not bounded by the current plant design basis-flood hazard, an Integrated Assessment will be necessary. The FHRR and the responses to the associated Requests for Additional Information (RAIs) will provide the hazard input necessary to complete the Integrated Assessment report, consistent with Japan Lessons-

Learned Project Directorate (JLD) interim staff guidance (ISG) JLD-ISG-2012-05, "Guidance for Performing the Integrated Assessment for External Flooding" (NRC, 2012c).

By letter dated March 11, 2013 (Mulligan, 2013), Entergy Operations, Inc. (Entergy, the licensee) provided its FHRR for Grand Gulf Nuclear Station, (Grand Gulf, GGNS) Unit 1. By email dated December 11, 2013 (NRC, 2013c), the NRC staff issued an RAI to the licensee. The licensee responded by letter dated January 9, 2014 (Mulligan, 2014). The licensee did not identify any interim actions.

Because a reevaluated flood-causing mechanism is not bounded by the current plant-specific design-basis hazard, the staff anticipates submittal of an Integrated Assessment. The staff will prepare an additional staff assessment report to document its review of the Integrated Assessment.

The licensee submitted a separate flooding walkdown report dated November 26, 2012, in response to Near-Term Task Force Recommendation 2.3 (Perito, 2012). The staff prepared a separate staff assessment report to document its review of the licensee's flooding walkdown report (NRC, 2014).

2.0 REGULATORY BACKGROUND

2.1 Applicable Regulatory Requirements

As stated above, Enclosure 2 to the 50.54(f) letter requested that licensees reevaluate flood hazards for their respective sites using present-day methods and regulatory guidance used by the NRC staff when reviewing applications for ESPs and COLs. This section describes present-day regulatory requirements that are applicable to the FHRR.

Section 50.34(a)(1), (a)(3), (a)(4), (b)(1), (b)(2), and (b)(4), of 10 CFR, describes the required content of the preliminary and final safety analysis reports (FSARs), including a discussion of the facility site with a particular emphasis on the site evaluation factors identified in 10 CFR Part 100. The licensee should provide any pertinent information identified or developed since the submittal of the preliminary safety analysis report in the FSAR.

Section 50.54(f) of 10 CFR states that a licensee shall at any time before expiration of its license, upon request of the Commission, submit written statements, signed under oath or affirmation, to enable the Commission to determine whether or not the license should be modified, suspended, or revoked. The 50.54(f) letter requested licensees reevaluate the flood-causing mechanisms for their respective sites using present-day methodologies and regulatory guidance used by the NRC for the ESP and COL reviews.

General Design Criterion 2 in Appendix A of Part 50 states that structures, systems, and components (SSCs) important to safety at nuclear power plants must be designed to withstand the effects of natural phenomena such as earthquakes, tornados, hurricanes, floods, tsunamis, and seiches without loss of capability to perform their intended safety functions. The design bases for these SSCs are to reflect appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area. The design bases are also to have sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

Section 50.2 of 10 CFR defines the design-basis as the information that identifies the specific functions that an SSC of a facility must perform, and the specific values or ranges of values chosen for controlling parameters as reference bounds for design which each licensee is required to develop and maintain. These values may be (a) restraints derived from generally accepted "state of the art" practices for achieving functional goals, or (b) requirements derived from an analysis (based on calculation, experiments, or both) of the effects of a postulated accident for which an SSC must meet its functional goals.

Section 54.3 of 10 CFR defines the "current licensing basis" as: "the set of NRC requirements applicable to a specific plant and a licensee's written commitments for ensuring compliance with and operation within applicable NRC requirements and the plant-specific design basis (including all modifications and additions to such commitments over the life of the license) that are docketed and in effect." This includes 10 CFR parts 2, 19, 20, 21, 26, 30, 40, 50, 51, 52, 54, 55, 70, 72, 73, 100 and appendices thereto; orders; license conditions; exemptions; and technical specifications as well as the plant-specific design-basis information as documented in the most recent FSAR. The licensee's commitments made in docketed licensing correspondence, which remain in effect, are also considered part of the current licensing basis.

Present-day regulations for reactor site criteria (Subpart B to 10 CFR Part 100 for applications on or after January 10, 1997) state, in part, that the physical characteristics of the site must be evaluated and site parameters established such that potential threats from such physical characteristics will pose no undue risk to the type of facility proposed to be located at the site. Factors to be considered when evaluating sites include, the nature and proximity of dams and other man-related hazards (10 CFR 100.20(b)) and the physical characteristics of the site, including the hydrology (10 CFR 100.21(d)).

2.2 Enclosure 2 to 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 ESP and 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 will be necessary.

2.2.1 Flood-Causing Mechanisms

Attachment 1 to Recommendation 2.1, Flooding (Enclosure 2 of the 50.54(f) letter) discusses flood-causing mechanisms for the licensee to address in the FHRR. Table 2.2-1 lists the flood-causing mechanisms the licensee should consider. Table 2.2-1 also lists the corresponding Standard Review Plan (SRP) (NRC, 2007) sections and applicable ISG documents containing acceptance criteria and review procedures. The licensee should incorporate and report associated effects per JLD-ISG-2012-05 "Guidance for Performing the

Integrated Assessment for External Flooding," (NRC, 2012c) in addition to the maximum water level associated with each flood-causing mechanism.

2.2.2 Associated Effects

In reevaluating the flood-causing mechanisms, the "flood height and associated effects" should be considered. JLD-ISG-2012-05 (NRC, 2012c) defines "flood height and associated effects" as the maximum stillwater surface elevation plus:

- wind waves and run-up effects
- hydrodynamic loading, including debris
- effects caused by sediment deposition and erosion
- concurrent site conditions, including adverse weather conditions
- groundwater ingress
- other pertinent factors

2.2.3 Combined Effect Flood

The worst flooding at a site that may result from a reasonable combination of individual flooding mechanisms is sometimes referred to as a "Combined Effect Flood." Even if some or all of these individual flood-causing mechanisms are less severe than their worst-case occurrence, their combination may still exceed the most severe flooding effects from the worst-case occurrence of any single mechanism described in the 50.54(f) letter (See SRP Section 2.4.2, Area of Review 9.(NRC, 2007)). Attachment 1 of the 50.54(f) letter describes the "Combined Effect Flood" as defined in American National Standards Institute/American Nuclear Society (ANSI/ANS) 2.8-1992 (ANSI/ANS, 1992) as follows:

> *For flood hazard associated with combined events,* [1] *American Nuclear Society (ANS) 2.8-1992 provides guidance for combination of flood causing mechanisms for flood hazard at nuclear power reactor sites. In addition to those listed in the ANS guidance, additional plausible combined events should be considered on a site-specific basis and should be based on the impacts of other flood causing mechanisms and the location of the site.*

If two less severe mechanisms are plausibly combined (per ANSI/ANS-2.8-1992 (ANSI/ANS, 1992) and SRP (NRC, 2007) Section 2.4.2, Areas of Review 9), then the staff will document and report the result as part of one of the hazard sections. An example of a situation where this may occur is flooding at a riverine site located where the river enters the ocean. For this site, storm surge and river flooding should be plausibly combined.

[1] For the purposes of this Staff Assessment, the terms "combined effects" and "combined events" are synonyms.

2.2.4 Flood Event Duration

Flood event duration was defined in the ISG for the Integrated Assessment for external flooding, JLD-ISG-2012-05 (NRC, 2012c), as the length of time during which the flood event affects the site. It begins when conditions are met for entry into a flood procedure, or with notification of an impending flood (e.g., a flood forecast or notification of dam failure), and includes preparation for the flood. It continues during the period of inundation, and ends when water recedes from the site and the plant reaches a safe and stable state that can be maintained indefinitely. Figure 2.2-1 illustrates flood event duration.

2.2.5 Actions Following the 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

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 at this time.

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of GGNS, Unit 1. 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. The staff's review and evaluation is provided below.

The licensee's flood hazard reevaluation studies were conducted using conventional units of measure. In this report, conventional units are followed by the equivalent measurement in metric units. Because the conversion to metric units may involve loss of precision, the measurement in conventional units is definitive.

The plant grade at the powerblock is elevation 132.5 feet (ft) (40.39 m) mean sea level (MSL). Unless otherwise stated, all elevations in this staff assessment are given with respect to MSL on the National Geodetic Vertical Datum of 1929 (NGVD29). Table 3.0-1 provides the summary of controlling reevaluated flood-causing mechanisms as well as Integrated Assessment triggered mechanisms, including associated effects that the licensee computed to be higher than the corresponding design-basis flood elevation.

3.1 Site Information

The 50.54(f) letter includes the SSCs important to safety, and the Ultimate Heat Sink, in the scope of the hazard reevaluation. Per the 50.54(f) letter, Enclosure 2, Requested Information, Hazard Reevaluation Report, Item a, the licensee included pertinent data concerning these SSCs in the FHRR.

The staff requested additional information from the licensee to supplement the FHRR. The licensee provided this additional information (Mulligan, 2014), which is discussed in the appropriate sections below.

The 50.54(f) letter, Enclosure 2 (Recommendation 2.1: Flooding), Requested Information, Item a, describes site information to be contained in the FHRR. The staff reviewed and summarized this information as follows.

3.1.1 Detailed Site Information

The licensee describes in its FHRR the following site information related to the site flood hazard analysis: The Grand Gulf site is located approximately 6 miles (10 km) northwest of Post Gibson, Mississippi. The site is situated on an elevated terrace approximately one mile (1.6 km) east of the Mississippi River, and approximately 0.5 miles (0.8 km) from the bluffs bounding the eastern edge of the river. The site boundary encompasses 2,015 acres (8.2 km^2).

The plant grade elevation is 132.5 ft (40.39 m), well above the bottom elevations of the Mississippi River, which range from 55 to 75 ft (16.76 to 22.86 m) in the vicinity of the site. The natural river floodplain near the site is approximately 60 miles (97 km) wide; however the flow in the river is confined to a width of approximately 2 to 4 miles (3.2 to 6.4 km) by high bluffs on the east bank and man-made levees with top elevations ranging from 101 to 103 ft (30.78 to 31.39 m) on the west bank. The river has a width of approximately 1 mile (1.6 km) during the dry season and 4 miles (6.4 km) during the wet season.

Finished floor grade elevations for all entries to safety-related SSCs are at or above 133 ft (40.54 m). The power block area is completely surrounded by concrete vehicle barriers. Gaps between barriers allow flowing of local intense precipitation (LIP) runoff to the surrounding drainage channels. The channels are connected to the surrounding two unnamed streams: Stream A and Stream B. The drainage areas of both streams are 2.8 and 0.6 square miles (7.2 to 1.6 km^2), respectively. These two streams flow to the Mississippi River.

The licensee provided in the FHRR the site layouts and features of the safety-related structures and the ultimate heat sink systems. More detailed descriptions of the plant facilities are found in the GGNS Unit 1 Updated Final Safety Analysis Report (UFSAR) (GGNS, 2012) and Early Site Permit Site Safety Analysis Report (SERI, 2005).

The licensee identified safety-related SSCs or flood doorways that can be potentially impacted by the LIP flood events. The doorways include two doors on the Control Building, five doors on the Diesel Generator Building, and four doors and two separate equipment/switchgears on Standby Service Water Basins A and B. The UFSAR Section 2.4.11.5.1 states that the radial wells are able to provide the necessary makeup to the Ultimate Heat Sink under any combination of plant demands and water availability. The radial collector wells are not required to be operable following an accident because the standby service water basins have sufficient capacity for 30 days of operation and makeup is not required during that period.

3.1.2 Design-Basis Flood Hazards

The current design-basis flood elevations described in the UFSAR (GGNS, 2012) are summarized in Table 3.1-1. The current design-basis flood hazard was estimated in accordance with NRC Regulatory Guide 1.59 (NRC, 1977). The controlling design-basis flood level is based on the estimated maximum water level caused by a LIP event with the assumptions that the onsite storm drains are inoperable, and that the culverts are blocked with an exception of Culvert 1, which is a 15 ft (4.6 m) diameter metal pipe to drain water from the powerblock area to the south. The licensee estimated in the UFSAR a maximum LIP flooding level of 133.25 ft (40.61 m) for an onsite 6-hour Probable Maximum Precipitation (PMP) value of 30.5 inches (77.47 cm).

FHRR Section 2.1.1 states that the finished floor grade for all entryways to safety-related SSCs are at or above 133 ft (40.54 m). The licensee chose a flood protection level of 133 ft (40.54 m), for which the duration of inundation is about 7 hours (GGNS, 2012). However, Table 3.4-1 in the same UFSAR states that, for structures, penetrations, and access doors and openings designed for flood protection, the probable maximum flood (PMF) level is 103 ft (31.39 m) and the design water level is 114.6 ft (34.93 m), which exceeds the maximum groundwater level of 113 ft (34.44 m). Because the licensee's description of the design-basis flood levels in the FHRR is different from the one presented on the Table 3.4-1 of UFSAR (GGNS, 2012), the staff issued RAI 3.1-1 (NRC, 2013c). In its response dated January 9, 2014, the licensee clarified that the design water level on the Table 3.4-1 in the UFSAR is actually the design groundwater level used in structural design (Mulligan, 2014).

3.1.3 Flood-related Changes to the Licensing Basis

The current licensing basis flood levels, which are identical to the current design-basis flood levels, are presented in the UFSAR (GGNS, 2012). The licensee stated in the FHRR that there is no change from the design basis flood hazards to the licensing basis flood hazards. The two significant current licensing basis flood values are summarized below, whereas all other flood causing mechanisms were screened out by the licensee:

- LIP flood elevation: 133.25 ft (40.61 m)
- Probable Maximum Flood on streams and rivers:
    - Mississippi River: 103 ft (31.39 m) MSL or 108.8 ft (33.16 m) with wind effects
    - Stream A: 128.93 ft (39.30 m) (Wind effects are not applicable)
    - Stream B: 132.80 ft (40.48 m) (Wind effects are not applicable)

3.1.4 Changes to the Watershed and Local Area

The licensee noted in FHRR Section 2.5.2 that, other than minor natural or man-made changes to stabilize the channel of the Mississippi River, there has been no significant change to the Mississippi River watershed or other streams and rivers in the vicinity of the site after the operation of the plant began in 1974. The primary site change pertinent to LIP flood analyses is the installation of the concrete vehicle barriers. The licensee analyzed in the FHRR the effects of the barriers on the LIP flood modeling, as discussed in the LIP flood section of this report.

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

The licensee stated in FHRR Section 2.3.2 that the design-basis flood level caused by a LIP event will exceed the plant grade elevation of 133 ft (40.54 m), and that there is a potential for leakage through external doors or openings to many safety-related buildings and facilities. Correspondingly, the licensee provided the following flood protections and mitigation features:

- Water leaking into the Control and Diesel Generator Buildings could affect safety-related SSCs. Water entering the Standard Service Water Pump Houses through the doorways, equipment hatches, and floor penetrations could affect safety-related electrical equipment. Therefore, watertight door seals (up to 1 ft (0.3 m) above from the floor) were installed on 11 doors to the Control Building, the Diesel Generator Building, and the Standby Service Water pump houses.
- Several modifications to the floor and exterior walls, door sealants, penetration sleeves, toe plates, and curbs were provide to protect the facilities from flooding.
- To protect the Standby Service Water Pump Houses specifically, curbs and toe plates were installed to isolate safety-related equipment from flooding.

The licensee stated in FHRR Section 2.3.2 that passive features are required to be installed per existing Off-Normal Event Procedures. These procedures require sand bags to be installed around all PMP sealed doors whenever the 24-hour weather forecast calls for rainfall amounts of 12 in (0.3 m) or more.

3.1.6 Additional Site Details to Assess the Flood Hazard

The licensee provided electronic copies of the input and output files used for FLO-2D, HEC-HMS, and HEC-RAS modeling related to the LIP and river flood analyses in response to RAI 3.2-6 (Mulligan, 2014).

3.1.7 Results of Plant Walkdown Activities

Requested Information Item 1.c and Attachment 1 to Enclosure 2, Step 6, of the 50.54(f) letter, asked the licensee to report any relevant information from the results of the plant walkdown activities associated with Enclosure 4 (NRC, 2012a). On November 26, 2012, the licensee submitted a walkdown report in response to the request (Perito, 2012).

The staff prepared a staff assessment report, dated June 23, 2014 (NRC, 2014), to document its review of the walkdown report. The staff concluded that the licensee's implementation of flooding walkdown methodology met the intent of the walkdown guidance.

3.2 <u>Local Intense Precipitation and Associated Site Drainage</u>

The licensee reported in its FHRR that the reevaluated flood hazard, including associated effects of debris and sedimentation, but no wind effects, for 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 UFSAR (GGNS, 2012). The current design-basis hazard for the LIP and associated site drainage hazard is 133.25 ft (40.61 m).

The 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 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) NGVD29. In addition, equipment and switchgear for each of the two standby service water basins were considered in the reevaluation. The licensee provided in the FHRR time-series plots of the water elevations during a LIP event for each of the safety-related features mentioned above.

The licensee reported a 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 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 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 staff reviewed its earlier determination and noted that neither the present standard methods nor values associated with estimating the PMP have changed since the staff's ESP review.

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 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). 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 SSCs 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 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 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 staff reviewed the FLO-2D model input and output related to the LIP runoff analyses provided by the licensee. The staff identified multiple modeling components of the LIP runoff analyses that appeared to be inconsistent with the descriptions provided by the licensee (Mulligan, 2013; Mulligan, 2014). Because the LIP flooding mechanism is included as part of an Integrated Assessment, the staff determined that these numerical modeling issues should be resolved as part of the Integrated Assessment. These issues are identified as Integrated Assessment Open Items, and are listed in Table 5.0-1. The Integrated Assessment Open Items related to the LIP flood modeling are:

- Integrated Assessment Open Item 1a: 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 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 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.
- Integrated Assessment Open Item 1b: The staff could not verify that the 50 percent culvert blockage was appropriately implemented in the FLO-2D model. The licensee is requested to clarify how the reduced culvert discharge had actually been modeled for Culverts 8A, 9A, and 11. The licensee is also requested to clarify that Culvert 1 was configured as described by the licensee in its FHRR and RAI responses.
- Integrated Assessment Open Item 1c: The licensee is requested to resolve staff-identified numerical modeling issues related to the LIP FLO-2D simulations, including inaccurate water budgets and unrealistic long-tails on the simulated stage hydrographs presented in FHRR Figures 3.1-9, 3.1-10, 3.1-14, and 3.1-16.
- Integrated Assessment Open Item 2: The licensee is requested to justify the proposed blocking assumptions of the onsite drainage system (e.g., supported by proposed maintenance and flood protection measures implemented through emergency procedures or administrative controls) consistent with the Integrated Assessment interim staff guidance (NRC, 2012c), and NUREG/CR-7046 (NRC, 2011e). In particular, the licensee is requested to justify the assumed 50-percent blockage of the 4-foot culverts and 30-percent blockage for vehicle barrier openings.

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 staff issued open items to justify the adequacy of the postulated culvert blocking scheme and the associated debris effects on LIP flood analyses. The 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. Therefore, the licensee stated that LIP and associated site drainage would be included within the scope of the Integrated Assessment. The information on flooding from LIP and associated site drainage that is specific to the data needs of the Integrated Assessment is described in Section 4 of this staff assessment.

The 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 should address the flood causing mechanism of LIP and associated site drainage within the scope of the Integrated Assessment after resolving the issues related to the roof drainage modeling, culvert blockage and the duration of LIP runoff analyses, as discussed in the Integrated Assessment Open Items Nos. 1 and 2.

3.3 Streams and Rivers

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 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 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 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 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 CEDAS-ACES 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 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 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 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 staff reviewed. The 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 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 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 staff reviewed the licensee-provided model input and output in terms of volume conservation, area of inundation, and maximum water velocities. The 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 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 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 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 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 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 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 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 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 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 staff determined that the general methods described in the licensee's FHRR are consistent with present-day methods. The 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 staff confirmed that the reevaluated flood hazard for streams and rivers is not bounded by the current design-basis flood hazard. This is consistent with the licensee's response to RAI 4.0-1 (Mulligan, 2014), which states that flooding on streams and rivers will be included in the Integrated Assessment. Therefore, the licensee should include flooding from streams and rivers, specifically Stream A, within the scope of the Integrated Assessment.

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 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 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 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 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 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 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 staff calculated the breach peak outflow attenuated to the site using the Froehlich breach peak equation (1995) and the flow attenuation equation by USBR (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 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 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 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 FHRR 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 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 staff also performed a simple bounding dam failure flood analysis on the Bayou Pierre. The 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 staff assumed that all dams fail and discharge water to the basin outlet simultaneously without loss. The 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 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 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 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 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 staff identified no onsite water control or storage structures that could cause potential dam failure flooding to the plant site.

The 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. This is consistent with the licensee's response to RAI 4.0-1 (Mulligan, 2014), which states that flooding on streams and rivers, dam breaches and failures, and their combined events will be included in the Integrated Assessment: However the licensee stated it will be a simplified process as protection is provided by natural terrain. Therefore the licensee should include dam failure flood analysis on Mississippi River within the scope of the Integrated Assessment.

3.5 Storm Surge

The licensee reported in the FHRR that the reevaluated hazard, including associated effects, for site flooding due to storm surge does not inundate the site. This flood-causing mechanism is described in the licensee's current design basis, where the licensee screened out storm surge as a plausible flood causing mechanism for the site.

The licensee described in the FHRR that the site is not expected to be flooded from ocean storm surge because the site is located approximately 406 river miles (653 river km) inland from the Gulf of Mexico with the site grade of 132.5 ft (40.39 m). There is no significant water body that is subject to surges on the plant site. Therefore, the licensee did not perform a detailed reevaluation for flooding caused by storm surge for the site in its FHRR.

In summary, the staff confirmed the licensee's conclusion that reevaluated hazard for flooding from storm surge is bounded by the current design basis flood hazard.

3.6 Seiche

The licensee reported in its FHRR that the reevaluated hazard, including associated effects, for site flooding due to seiche effects does not inundate the plant site. This flood-causing mechanism is described in the licensee's current design-basis, where the licensee screened out seiche as a plausible flood causing mechanism for the site.

The licensee stated in its FHRR that the site is approximately 1,800 ft (550 m) away from the Mississippi River with the site grade of 132.5 ft (40.39 m). Therefore, the licensee did not perform a detailed reevaluation for flooding caused by seiche in the FHRR.

In summary, the staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from seiche alone could not inundate the site. The staff confirmed that the reevaluated hazard for flooding from seiche is bounded by the current design basis flood hazard.

3.7 Tsunami

The licensee reported in its FHRR that the reevaluated hazard, including associated effects, for site flooding due to tsunami does not affect the site due to its location on a high inland area which is far from any large body of water. This flood-causing mechanism is described in the licensee's current design-basis, where the licensee screened out tsunami as a plausible flood causing mechanism for the site.

The licensee concluded in its FHRR that the site is not expected to be flooded by tsunami because the site is located approximately 406 river miles (653 river km) inland from the Gulf of Mexico with the site grade of 132.5 ft (40.39 m). Therefore, the licensee did not perform a detailed reevaluation of flooding caused by tsunami.

In summary, the staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from tsunami alone could not inundate the site. The staff confirmed that the reevaluated hazard for flooding from tsunami is bounded by the current design-basis flood hazard.

3.8 Ice-Induced Flooding

The licensee reported in its FHRR that the reevaluated hazard, including associated effects, for ice-induced flooding does not inundate the plant site. This flood-causing mechanism is described in the licensee's current design-basis.

The licensee analyzed in its FHRR historical ice events and found no historical records of ice jams on the Mississippi River in the vicinity of the plant site. The licensee also evaluated water temperature data in the river from 1962 to 2012, and identified only one occasion for which temperatures were below freezing. Further, the licensee noted that the USACE maintains navigable conditions on the Lower Mississippi River at all times. Therefore, the licensee concluded that ice-induced flooding on the Mississippi River is not anticipated.

The staff reviewed the potential for ice-induced flooding in the Grand Gulf ESP application. NUREG-1840 (NRC, 2006) concluded that there is no outstanding issue related to ice-induced flooding at the site. The staff noted that there have been no substantial changes in climate and environments since NUREG-1840's issuance, and that ice-induced flooding is similarly not expected in the Bayou Pierre basin located further south on the Mississippi River. The staff also checked the ice jam database of the U.S. Army Corps of Engineers (USACE, 2012), and confirmed that there are no outstanding ice jams and associated floods on the Mississippi River near the site or Bayou Pierre.

In summary, the staff confirmed the licensee's conclusion that the reevaluated hazard from ice-induced flooding alone could not inundate the site. The staff confirmed that the reevaluated hazard for ice-induced flooding of the site is bounded by the current design-basis flood hazard.

3.9 Channel Migrations or Diversions

The licensee reported in its FHRR that the reevaluated hazard, including associated effects, for site flooding due to channel migrations or diversions does not inundate the site. This flood-causing mechanism is described in the licensee's current design-basis, where the licensee screened out channel migrations and diversions as a plausible flood causing mechanism for the site.

The licensee analyzed the potential for channel migrations and diversions near the vicinity of the site with respect to historical records and hydrogeomorphological data. The licensee described that lateral shifting of the Mississippi River near the site is a known historical issue. Therefore, the USACE constructed revetments along the east bank of the river near the site to prevent channel migration, as well as submerged dikes across the west channel to divert flow to the east channel. Additional revetment and dike construction and channel stabilization work have been planned near the site. Therefore, the licensee concluded that the potential for river channel migration to impact site flooding is negligible.

The NRC staff reviewed the Grand Gulf, Units 2 and 3 ESP and associated additional documents. As a result, the staff confirmed that there is no outstanding issue related to the channel division and migration flooding, and that, in order to cause flooding at the site, the Mississippi River would have to erode through more than about 100 ft (30 m) of terrain, which has not been observed historically. Therefore, the staff concluded in NUREG-1840 that flooding caused by channel migrations and diversions is highly unlikely.

The staff noted that although flooding from the Bayou Pierre will not directly affect the plant site, there is the potential for the river to be diverted to the site by erosion or landslide from the cliffs narrowing the channel. Because the FHRR does not address flooding to the site caused by the channel diversion or the combined events of channel diversion with river PMF and upstream dam failures, in RAI No. 3.3-3, the staff requested the licensee to provide an analysis of flooding caused by Bayou Pierre channel diversion or the combined events of channel diversion with PMF and dam failure. In its response dated January 9, 2014 (Mulligan, 2014), the licensee concluded that, based on a simple bounding analysis, the combined flood event of PMF and dam failure is highly unlikely to overtop the Bayou Pierre watershed divide at GGNS and cause flooding at GGNS. They noted that the Bayou Pierre is separated from the plant site by a natural watershed divide with a top elevation of approximately 175 ft (53.34 m). The licensee also described that the potential channel migration, diversion, and landslide in Bayou Pierre is not considered plausible based on a review of the USGS topography data. Therefore, the licensee concluded that channel diversions or landslides on the river are not considered a credible source of flooding to the plant site. The staff reviewed the RAI response and agrees with the licensee's conclusion that the site flooding associated with the channel diversion on Bayou Pierre, as well as Streams A and B and the associated combined event floods is not a plausible scenario because the banks of the channels are not prone to erosion.

In summary, the staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from channel migrations or diversions could not inundate the site. The staff confirmed that the reevaluated hazard for flooding from channel migrations or diversions is bounded by the current design-basis flood hazard.

4.0 INTEGRATED ASSESSMENT AND ASSOCIATED HAZARD DATA

The licensee stated the following in the response to RAI No. 4.0-1 (Mulligan, 2014):

> Local Intense Precipitation is the controlling flood for Grand Gulf Nuclear Station and will be included in the Integrated Assessment. Flooding on Rivers and Streams, Dam Breaches and Failures, and Combined Effects are at or below site grade of 132.5'. They will be included in the Integrated Assessment Report however will be a simplified process as protection is provided by natural terrain.

The staff agrees with the licensee's conclusion that an Integrated Assessment is necessary and that the Integrated Assessment should consider the flood-causing mechanisms of LIP, stream and river, and dam failure flooding including their potential combined events with applicable associated effects. The staff also agrees with the licensee's conclusions that flooding from streams and rivers, dam failures, and combined effects, remains below the plant grade. Therefore, the staff expects that the resulting scope of the portion of the Integrated Assessment addressing flooding from streams and rivers, dam failures, and combined effects will be limited.

Section 5 of JLD-ISG-2012-05 (NRC, 2012c) describes the flood hazard parameters needed to complete the Integrated Assessment. The staff reviewed the following subset of these flood hazard parameters to conclude that the flood hazard information is appropriate input to the Integrated Assessment:

- 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 staff's review of this combined event flooding is addressed in Section 3.4 of this 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 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 staff requested, via RAI No. 4.0-1, the licensee to provide the applicable flood event duration parameters associated with mechanisms that trigger an Integrated Assessment. 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. The licensee noted that LIP flooding will be included in the Integrated Assessment.

In Figures 3.1-6 through 3.1-19 of the 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 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. The staff plans to further evaluate the basis for flood event duration parameters (e.g., warning time based on available forecast methods) as part of the Integrated Assessment.

The staff identified two Integrated Assessment Open Items related to the LIP flooding analyses in the Section 3.2 of this report that should be addressed by the licensee in the Integrated Assessment. The licensee's LIP flood analyses are based on a six-hour PMP event. The staff noted from the results of FLO-2D simulations for other sites that long duration PMP events (e.g., 24, 48, and 72-hour PMPs) may result in a higher water surface elevation and longer period of inundation, while short duration PMP events (e.g., one, and six-hour PMPs) may result in shorter warning times and in a flood above the elevation of openings to plant structures. Therefore, the staff identified the following Integrated Assessment Open Item 3: As part of the Integrated Assessment, the licensee should evaluate the plant response for a range of rainfall durations associated with the LIP hazard events (e.g., 1, 6, 12, 24, 48, and 72-hour PMPs) to determine the controlling LIP scenarios (NRC, 2012c). This should include a sensitivity analysis to identify potentially limiting scenarios with respect to plant response when considering flood height, relevant associated effects, and flood event duration parameters. Flood elevation duration parameters are provided for the six-hour event only in Table 4.0-1. Table 5.0-1 summarizes all Integrated Assessment Open Items that should be addressed in the Integrated Assessment.

The staff confirmed that the reevaluated flood hazard information defined in the sections above is appropriate input to the Integrated Assessment, with the exception of the Integrated Assessment Open Items listed in Table 5.0-1. The staff will evaluate Integrated Assessment Open Items and the bases for flood duration parameters (e.g., warning time based on existing agreements) as part of the Integrated Assessment.

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 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 upon the preceding analysis, the NRC staff confirmed that the licensee responded appropriately to Enclosure 2, Required Response 2, of the 50.54(f) letter, dated March 12, 2012. In reaching this determination, the staff confirmed the licensee's conclusions that (a) the reevaluated flood hazard results for local intense precipitation, streams and river flooding, and dam failure flooding are not bounded by the current design-basis flood hazard, (b) an Integrated Assessment including LIP flooding, streams and river flooding, and dam failure flooding is expected to be submitted by the licensee, and (c) the reevaluated flood-causing mechanism information is appropriate input to the Integrated Assessment as described in JLD-ISG-2012-05 (NRC, 2012c). The NRC staff identified three Integrated Assessment Open Items related to the FLO-2D analysis and the assumptions to establishing conservative LIP flood event duration parameters. The Integrated Assessment Open Items are summarized in Table 5.0-1. Therefore, the NRC is not providing finality on the flood parameters related to the LIP and associated site drainage as part of this staff assessment.

6.0 REFERENCES

ADAMS Accession Nos. refers to documents available through NRC's Agencywide Documents Access and Management System (ADAMS). Publicly-available ADAMS documents may be accessed through http://www.nrc.gov/reading-rm/adams.html.

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- U.S. Nuclear Regulatory Commission (NRC), 1977, "Design Basis Flood for Nuclear Power Plants," Regulatory Guide 1.59, Rev. 4, 1977.

- NRC, 2006. "Safety Evaluation of Early Site Permit Application in the Matter of System Energy Resources, Inc., A subsidiary of Entergy Corporation, for the Grand Gulf Early Site Permit Site". NUREG-1840. April 2006. Adams Accession No. ML061070443.

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- NRC, 2013a, "Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment," Japan Lessons-Learned Project Directorate, Interim Staff Guidance JLD-ISG-2012-06, Revision 0, January 4, 2013, (2013a), ADAMS Accession No. ML12314A412.

- NRC, 2013b, "Guidance for Assessment of Flooding Hazards Due to Dam Failure," Japan Lessons-Learned Project Directorate, Interim Staff Guidance JLD-ISG-2013-01, July 29, 2013, ADAMS Accession No. ML13151A153.

- NRC, 2013c, "Grand Gulf Nuclear Station Request for Additional Information Regarding Flooding Hazard (TAC MF1102)", ADAMS Accession No. ML13345A222.

- NRC, 2014, "Grand Gulf Nuclear Station – Staff Assessment of the Walkdown Report Supporting Implementation of Near-term Task Force Recommendation 2.3 Related to the Fukushima Dai-Chi Nuclear Power Plant Accident, (TAC MF0232)", ADAMS Accession No. ML14147A374.

6.2 Codes and Standards

- ANSI/ANS (American National Standards Institute/American Nuclear Society), 1992, ANSI/ANS-2.8-1992, "Determining Design Basis Flooding at Power Reactor Sites," American Nuclear Society, LaGrange Park, IL, July 1992.

6.3 Other References:

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- FLO-2D Software Inc., 2009, FLO-2D® v.2009 User's Manual, FLO-2D Software, Inc., Nutrioso, Arizona, 2009.

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Table 2.2-1: Flood-Causing Mechanisms and Corresponding Guidance.

Flood-Causing Mechanism	SRP Section(s) and JLD-ISG
Local Intense Precipitation and Associated Drainage	SRP 2.4.2 SRP 2.4.3
Streams and Rivers	SRP 2.4.2 SRP 2.4.3
Failure of Dams and Onsite Water Control/Storage Structures	SRP 2.4.4 JLD-ISG-2013-01
Storm Surge	SRP 2.4.5 JLD-ISG-2012-06
Seiche	SRP 2.4.5 JLD-ISG-2012-06
Tsunami	SRP 2.4.6 JLD-ISG-2012-06
Ice-Induced	SRP 2.4.7
Channel Migrations or Diversions	SRP 2.4.9

Notes:
1. SRP is the Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition (NRC, 2007)
2. JLD-ISG-2012-06 is the "Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment" (NRC, 2013a)
3. JLD-ISFG-2013-01 is the "Guidance for Assessment of Flooding Hazards Due to Dam Failure" (NRC, 2013b)

Table 3.0-1: Summary of Controlling Flood-Causing Mechanisms

Reevaluated Flood-Causing Mechanisms that May Exceed the Powerblock Elevation (elevation 132.5 ft (40.39 m))	ELEVATION* (ft (m))
Local Intense Precipitation and Associated Drainage	133.7 (40.75)
PMF on Stream A (with wind effects)	132.5 (40.39)

***Flood Height and Associated Effects as defined in JLD-ISG-2012-05.**

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 to be Examined in the Integrated Assessment.

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. Values shown in this table may change as a result of Integrated Assessment Open Item 3.

(2) The licensee did not provide this value because Stream A PMF and flooding from dam failures will not inundate the site. The licensee is expected to provide this value if needed during the Integrated Assessment. 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 to be Examined in the Integrated Assessment.

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

Integrated Assessment Open Items: The Integrated Assessment Open Items set forth in the staff assessment and summarized in the table below identify certain matters that should be addressed in the Integrated Assessment submitted by the licensee. These items constitute information requirements, but do not form the only acceptable set of information. A licensee may depart from or omit these items, provided that the departure or omission is identified and justified in the Integrated Assessment. In addition, these items do not relieve a licensee from any requested information described in Part 2, Integrated Assessment, of the March 12, 2012, 10 CFR 50.54(f) letter, Enclosure 2.

Integrated Assessment Open Item No.	SA Section No.	Subject to be Addressed
1(a,b,c)	3.2	Resolve the staff-identified FLO-2D numerical modeling issues associated with the local intense precipitation flood analyses. Specifically, resolve issues related to the following as described in Section 3.2: a) runoff from rooftops being removed from the numerical model domain rather than discharging to the ground surface near the structure or an adjacent area. b) proper implementation of culvert blockage and associated configuration in FLO-2D. c) numerical FLO-2D modeling issues, such as inaccurate water budgets and unrealistic long-tails on the simulated stage hydrographs.
2	3.2/4.0	Justify the proposed blocking assumptions on the onsite drainage system (e.g., supported by proposed maintenance and flood protection measures implemented through emergency procedures or administrative controls) consistent with the Integrated Assessment interim staff guidance (NRC, 2012c). In particular, the licensee is requested to justify the assumed 50-percent blockage of the 4-foot culverts and 30-percent blockage for vehicle barrier openings.
3	4.0	Evaluate the plant response time considering a range of rainfall durations associated with the local intense precipitation flood hazard (e.g., 1, 6, 12, 24, 48, 72-hour PMPs). This evaluation should identify potentially limiting scenarios with respect to plant response when considering flood height, relevant associated effects, and flood event duration parameters.

Figure 2.2-1: Flood Event Duration

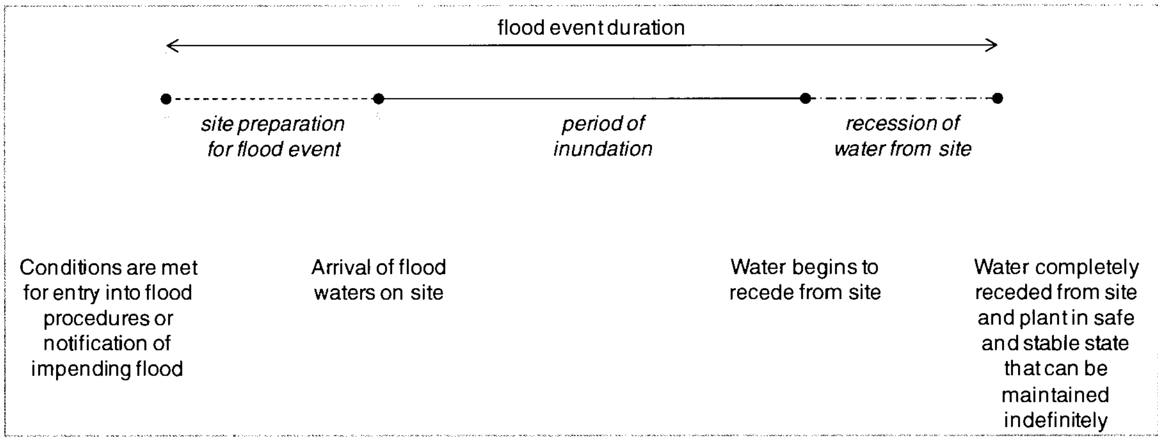


Figure 3.2-1: Site map with FLO-2D model grid, where brown color grid cells indicate building areas designated as area reduction factors (from the response of RAI 3.2-1 (Mulligan, 2014).

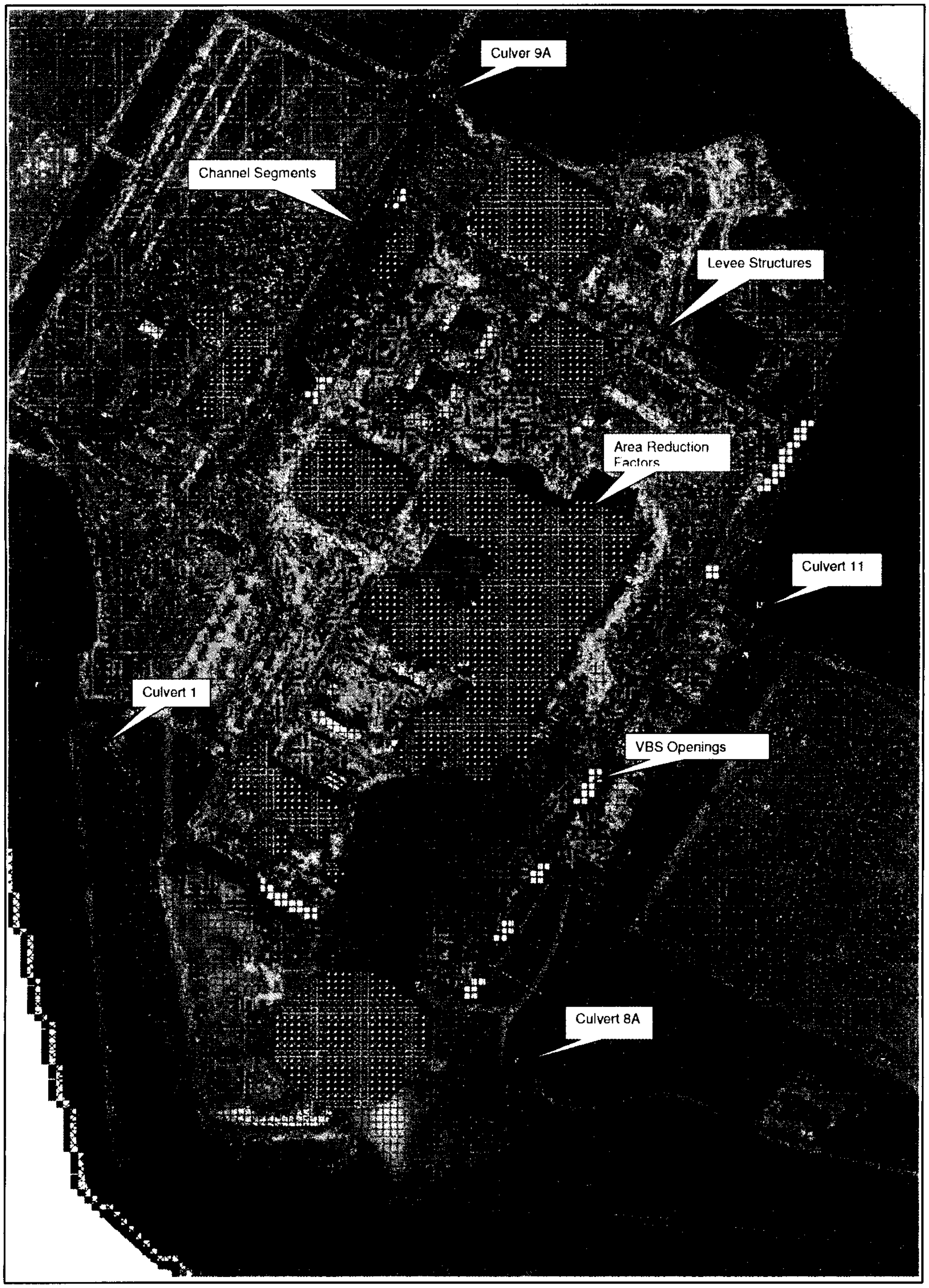


Figure 3.3-1: Stream A and Stream B basins obtained from Figure 2.4-8 of UFSAR Unit 1 (2012).

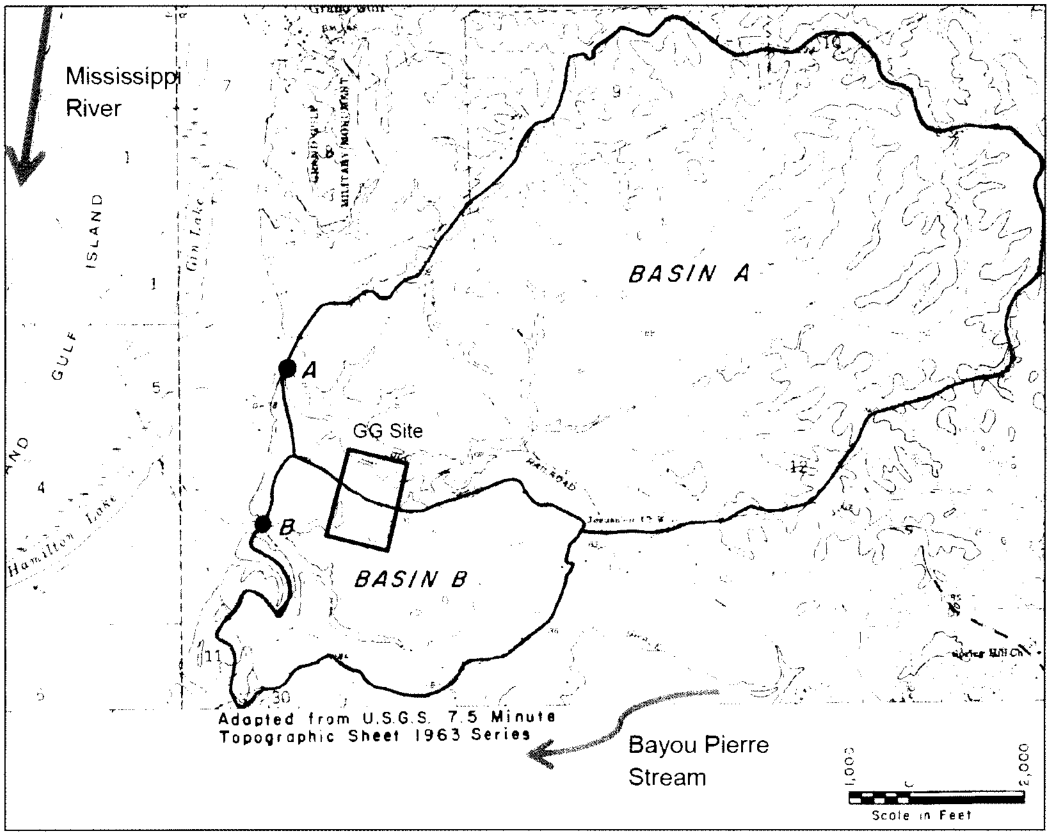


Figure 3.3-2: Rating curve for the Mississippi River at the Grand Gulf site, which was constructed using the information from Figure 2.4-15 of in UFSAR and the stage-discharge values (especially for stages greater than 30 m (100 ft) MSL) presented on page 3-34 of the FHRR.

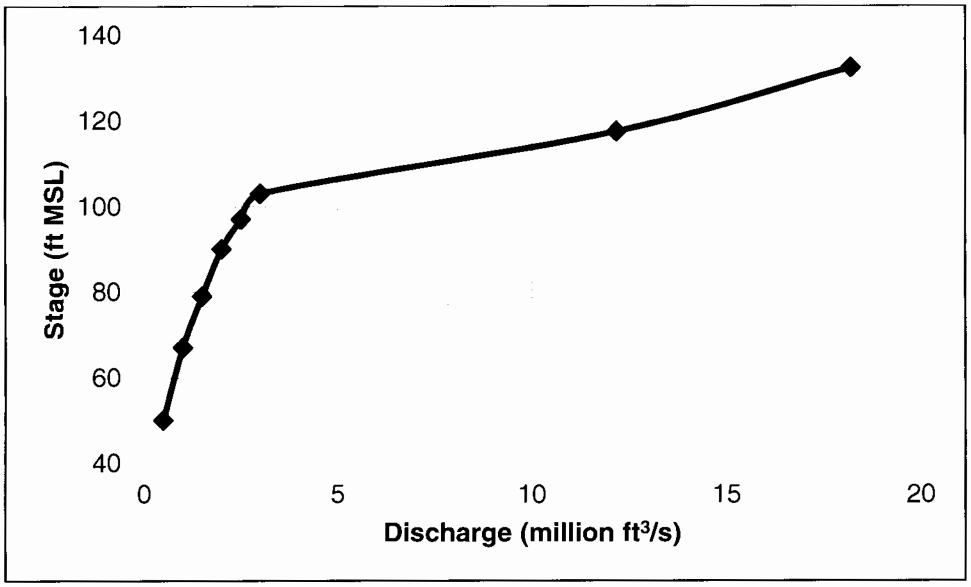
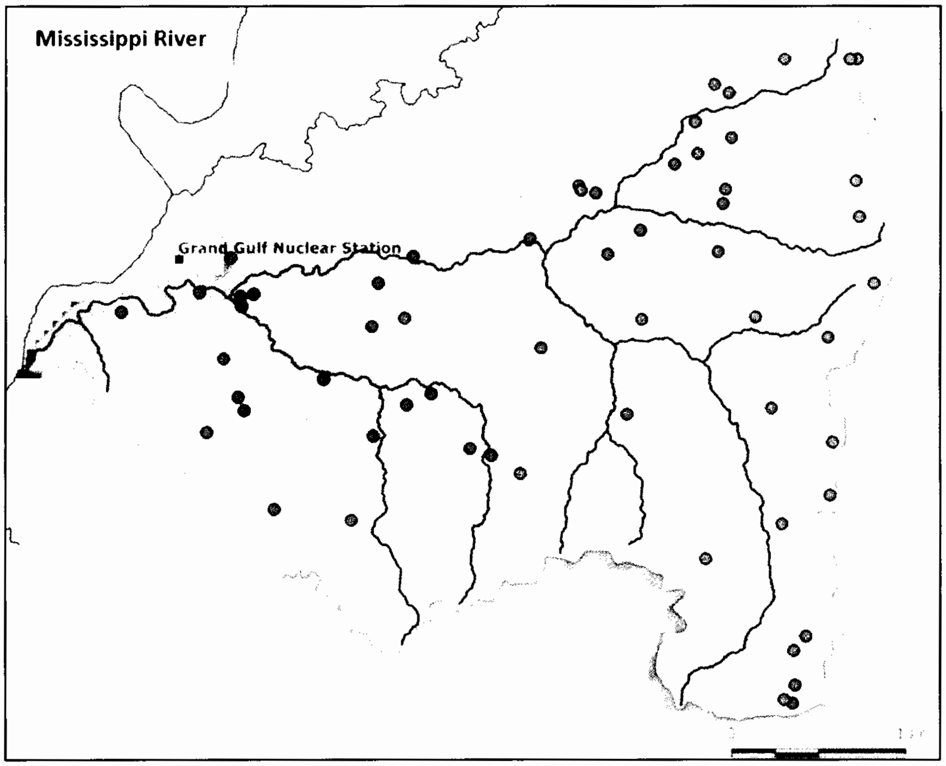


Figure 3.4-1: Bayou Pierre basin with dams (blue dots)



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

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Reevaluation Report

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